E09798

Cassell's Pet and Live Stock Series

1/6 *EACH Net, or* **1/9** *post free from CASSELL'S, Publishers, London.*

To those who keep pets for pleasure, and live stock for profit—in a small way—this series of little handbooks will prove of the greatest service, and are reliable beyond question.

PIGEONS: AND HOW TO KEEP THEM

LT.-COL. A. H. OSMAN, O.B.E.

Valuable advice on the selection of stock, management, feeding and breeding and the treatment of disease in pigeons.

BEEKEEPING UP-TO-DATE

A. B. FLOWER, F.E.S.

A valuable aid to amateurs and professionals for proper handling and manipulation of bees. A calendar for apiarists is included.

YOUR DOG

ROBERT LEIGHTON

Valuable information on the training, feeding, and general treatment of a dog. Also first-aid hints—in fact, everything a dog-owner ought to know.

CANARIES: AND HOW TO KEEP THEM

F. J. S. CHATTERTON

A guide to the successful keeping and rearing of canaries, either as pets or for breeding purposes.

MODERN PIG-KEEPING

H. P. JAQUES

Written primarily for the small man, but anyone who keeps pigs will find this book a valuable guide to making the pig pay.

DUCKS AND GEESE: AND HOW TO KEEP THEM

F. J. S. CHATTERTON

What are the best breeds to keep for egg-production, or for table purposes? How should they be housed and fed? These and a host of other important points are dealt with in this book.

POPULAR CAGE BIRDS

JOHN ROBSON

Authoritative information and directions on the proper management, keeping and breeding of these delightful pets.

PRACTICAL RABBIT-KEEPING

GEORGE A. TOWNSEND

This book will meet the needs of everyone who "goes in" for rabbit keeping, either as pets or for exhibition purposes.

FOWLS: AND HOW TO KEEP THEM

ROSSLYN MANNERING

Everyone who keeps fowls, whether in the expectation of profit-making, or merely as a hobby, will find this book a real practical help.

Cassell & Company, Ltd., Publishers, London

GRAMOPHONES
AND
PHONOGRAPHS

THEIR CONSTRUCTION,
MANAGEMENT AND REPAIR

BY

B. CLEMENTS-HENRY

ILLUSTRATED BY 103 LINE DRAWINGS

CASSELL AND COMPANY, LTD
London, Toronto, Melbourne and Sydney

First published *July* 1913.
Reprinted April 1914.
,, *January* 1917.
,, *May* 1918.
,, *September* 1919.
,, *June* 1920.
,, *December* 1921.
,, *January* 1923.
,, *March* 1925.
,, *May* 1927.

Printed in Great Britain

PREFACE

A SINGULARLY able writer on all matters relating to the talking machine provides in the following chapters a guide to the principles, choice, management, and detail construction of gramophones and phonographs. Every word is the outcome of the author's practical experience. Mr. Clements-Henry explains the method of making every part of the machine, and gives valuable hints on successful recording at home.

CONTENTS

CHAPTER PAGE
1. INTRODUCTION: PRINCIPLES OF SOUND REPRODUCTION 1
2. CHOOSING A TALKING MACHINE . . . 7
3. LUBRICATION, SPEED REGULATION, ETC. . . 13
4. REPRODUCERS, SOUND-BOXES, OR "SPEAKERS" 16
5. THE NEEDLE AND THE STYLUS . . . 32
6. MAKING A GRAMOPHONE REPRODUCER . . 38
7. MAKING A FLOATING REPRODUCER FOR A PHONOGRAPH 44
8. A SPEAKER-ARM FOR PHONOGRAPHS . . . 49
9. HORNS OR TRUMPETS 54
10. CONSTRUCTING A HIGH-GRADE GRAMOPHONE . 80
11. THE CONSTRUCTION OF A SPRING MOTOR. . 94
12. INSERTING NEW SPRINGS IN MOTORS . . 105
13. MAKING RECORDS AT HOME 108
14. MAKING RECORDERS FOR PHONOGRAPHS . . 133
15. MOULDING PHONOGRAPH WAX CYLINDERS . 141
16. CONTINUOUS FORWARD-WIND FOR EDISON "GEM" PHONOGRAPH 144
INDEX 150

LIST OF ILLUSTRATIONS

FIG. PAGE
1.—"Exhibition" Sound-box 21
2.—Floating-type Reproducer 21
3.—"Seymour" Reproducer 23
4.—Edison B Reproducer 23
5.—Edison C Reproducer 25
6 and 7.—Pneumatic Reproducer for Gramophone . . . 27
8.—Tone Arm for Gramophone 29
9.—Sound-magnifying Device for Phonograph 30
10.—Button-stylus 33
11.—The Button-stylus Set 33
12.—Ball-stylus 35
13.—Angle of Ball-stylus to Record 35
14.—Glass Stylus in Reproducer Dome 35
15 to 17.—Plan and Sections of Gramophone Reproducer . . 39
18 and 19.—Ring of Reproducer 40
20.—Part Section through Reproducer 40
21 and 22.—Ring Fitting 41
23 to 26.—Needle Fitting and Diaphragm Finger 41
27 to 29.—Plan, End Elevation, and Side Elevation of Floating Reproducer for Phonograph 45
30.—Sound-box of Floating Reproducer for Phonograph . . 47
31 and 32.—Side and Back Elevation of Speaker-arm adapted to "Gem" Machine 51
33 and 34.—Section and End View of Trumpet Stem . . . 52
35.—Horn of 12 Degrees Taper 56
36 and 37.—Comparative Diagrams of Horns 57
38.—Home-made Horn and Stand for Phonograph 59
39.—Horn Stand 59
40.—Pattern for 3-ft. Horn 59
41.—Fitting for Sliding Pivot Head 59
42.—46-in. Horn 65
43.—Pattern of 70-in. Horn 67
44.—Pattern of Flare 67
45.—Section through 70-in. Horn 69
46.—Half Plan of Flare, Rolled and Shaped 69
47.—Pattern of Pieces to be soldered to Gauge Lines . . . 69
48.—Elevation of Octagonal Horn 71

FIG. PAGE
49.—Part Plan of Octagonal Horn 71
50.—Side Pattern of Octagonal Horn 71
51.—Cardboard Horn 73
52.—Flare for Cardboard Horn 73
53.—Paper Horn 76
54 and 55.—Method of Rolling Paper Horn 77
56.—Bowl from which to make Flare 78
57.—The Flare made from Bowl 78
58.—Band for Paper Horn 78
59.—Section through Band 78
60.—Elevation of Gramophone Motor in Case 81
61.—Plan of Gramophone Motor in Case 81
62.—Elevation of Wooden Bracket supporting Tone-arm and Trumpet, with Framing Detail 84
63.—Milled Bolt and Nut for attaching Bracket to Cabinet . . 84
64.—Plan of Bracket Crown-fitting 85
65.—Slotted Trumpet-clamp 85
66.—Section through Articulated Horn or Trumpet-stem . . 89
67.—Sleeve and Bridge-piece 89
68.—Bridge-piece 89
69.—Hornless Gramophone 93
70 and 71.—Plan and Elevation of Motor 95
72.—Sectional Elevation of Motor Parts 97
73.—Edison's Recorder 113
74.—Gramophone or Floating Recorder 113
75.—Stylus and Method of Grinding 115
76 to 78.—Use of Resonators for making Vocal Records . . 125
79 to 81.—Recording Songs with Pianoforte Accompaniment . 127
82.—Double Y-union for Recording Horns 131
83 and 84.—Section and Plan of Edison-type Recorder . . . 133
85 to 87.—Front View, Back View and Section of Diaphragm Disc 134
88.—Tubular Weight 135
89 to 91.—Stylus Holder 136
92 and 93.—Alternative Forms of Stylus Holder 137
94 and 95.—Two Sections of Gramophone-type Recorder . . 138
96.—Built-up Recorder 139
97 and 98.—Simple Floating-type Recorder 139
99.—Recording Diaphragm for Gramophone 140
100.—Body of Mould 142
101.—Core to fit inside Cylindrical Body 142
102 and 103.—Continuous Forward-wind for Edison "Gem" Phonograph 145

GRAMOPHONES AND PHONOGRAPHS

CHAPTER I

Introduction: Principles of Sound Reproduction

THE principles involved in the reproduction of sound are briefly as follow: The talking machine depends for its action on the vibration of a disc, or drum-head, of thin, flexible material. The vibrations, varying in rapidity and magnitude, cause the diaphragm to emit sounds of varying pitch and volume. The vibrating disc is set at the apex of a conical horn, and its feeble sounds are amplified in their passage outwards by repercussion against the expanding walls of the horn.

Before sound can be reproduced, it must be "recorded" or "engraved" on a suitable surface. Original sounds of any kind set up waves or ripples in the surrounding atmosphere resembling those caused on water when a stone is cast into it. A given note sets up a definite number of aerial ripples per second, and these travel away from their source in all directions, until lost in space or deflected and confused by obstructions, the latter causing the phenomenon of echo.

Sound waves occurring in the proximity of solid matter set up synchronous, or similarly-timed, vibrations in it. Sounds directed into and focused by a hollow cone become intensified and concentrated at its apex or lesser end. A drum-head of thin and flexible material placed within this focus will, of course, vibrate vigorously. A needle-point or small cutting stylus attached to the diaphragm will vibrate with it. If this little tool rests on a plastic surface it will cut or puncture it as it vibrates. If the surface on which the cutter rests is made to move under it in one direction, the tool will engrave a line of dots and dashes corresponding in number and depth to the pitch and volume of the sounds focused by the horn.

If now the cutter be exchanged for a round-ended stylus or needle, and the line of dots be drawn under it in the same direction as before and at the same speed at which they were engraved, they will cause the flexible diaphragm to vibrate as before, and the hollow cone, amplifying the vibrations, will reproduce the original sounds that passed into it.

A hollow cone, or trumpet, acts as a sound magnifier by collecting the waves into one main channel, reflecting them from point to point along its inner surface and discharging them in the required direction. Sound is heard by individuals by the tympanum or drum of the ear being set in vibration, communicating its motion to two small bones called the malleus and incus, or mallet and anvil, which correspond to the microphone of a telephone apparatus, and which transmit the sensation to the brain by means of the aural nerves. Sound cannot be indefinitely increased; it may be condensed and driven one way;

and amplification is assisted by the vibrations of the metal trumpet itself, as further explained in Chapter IX.

Records are made in two forms—the cylinder and the disc. The former carries on its surface, from end to end, a fine-cut screw-thread. This thread or helical groove is of U-section, and on its bottom and sides are cast the dots and dashes engraved by the recording tool on the original or "master" record. As the cylinder revolves the thread forms a continuous track in which travels the ball or button of the reproducer. As the ball or button rises and falls over the inequalities at the bottom of the track it vibrates, and, being rigidly connected with the diaphragm, the vibrations are imparted to the latter, and thus sound is reproduced. The track on an ordinary shilling record is from 200 ft. to 250 ft. long.

Ordinary cylinders carry 100 threads to the inch; the Edison Company's Amberol brand has 200, giving a run of approximately 500 ft.

Cylindrical records are cast in a mould made from the original record engraved by the cutting stylus described above. The material of which they are composed is a saponified mixture of stearic acid, inorganic wax, and caustic alkali (see Chapter XV.).

Disc records have the track or groove impressed on their surfaces in an expanding or contracting spiral.

Two distinct methods of recording and reproduction are employed. By one method (that already referred to for cylinder records) the groove is of U-section, with the record impressed on its bottom and sides. This is technically known as the "phonograph-cut"; the running direction of the spiral is from the centre outwards, and a ball-stylus of sapphire is used for reproduction.

By the other method, the so-called "gramophone-cut," the groove is of V-section, smooth throughout but in itself sinuous or wavy. The reproducing stylus is in this case a steel needle, fitting the track. The sinuosities of the groove, as the disc revolves, impel the needle rapidly from side to side horizontally, and its movements are transmitted through a fulcrum to the vertically-supported diaphragm. The spiral travels from the circumference inwards towards the centre.

Discs are stamped in sheet material (superficially resembling ebonite or papier mâché) when the latter is in a plastic condition, from a metallic negative matrix formed electrically from the original "master."

The following paragraph (revised and corrected by a noted talking-machine firm) is quoted from the *Bazaar* because it clears up some of the confusion caused by a loose use of technical terms: "The gramophone was invented by H. Berliner, of Washington, to illustrate the practical use of Prof. Bell's discovery that the vibrations caused by any series of sounds could be 'written' by a vibrating point on a suitable material, and the same series of sounds reproduced by another point travelling over the inscription so made. It was one step in a long series of investigations resulting from a consideration of the properties of the telephone, invented by Prof. Bell, and this gramophone—so called from *gramma*, a letter, and *phone*, sound—consisted of a flat disc revolving horizontally and bearing on its surface the inscription impressed by the vibrating point. It had previously been discovered that a cylinder revolving on a spindle could take on the inscriptions, and that from these inscriptions the sounds could be reproduced by causing another point to travel along the engraved cylinder while the latter revolved on its spindle under the point. This primitive form of machine—the notion of Bell and Edison—was called a phonograph, from *phone*, sound, and *grapho*, I write. But all the machines distinguished in England as graphophones, phonographs, and gramophones, are called in the United States Patent Office graphophones, whatever other names makers may give them. The difference is not in the principle involved in the reproductions, but in the mechanism employed. Every talking machine now makes its records by engraving sound waves in a wax composition. This was first made known to the world by the inventors of the *graphophone;* the *phonograph* was a machine that indented its records on metal foil, whilst the *gramophone* etched its records in an acid bath. But the true phonograph or the true gramophone no longer exists, except as a curiosity. Every successful talking machine to-day employs the graphophone process of engraving its records, and is, therefore, strictly speaking, a graphophone."

At the present time, however, the term "graphophone" is almost obsolete; the disc machine is known as the "gramophone," and the cylinder machine as the "phonograph."

Disc machines have become the more popular type, because, in a general way, they may be said to yield more powerful reproductions than the cylinder machines. Given, however, a first-class record and a perfectly adjusted reproducer of either type, there is little to choose in the matter of distinct utterance. In one particular, up to the present, both machines fail, more or less, and that is in the reproduction of sibilant sounds at their correct values. The aspirate consonant "s," in many words, becomes modified to "sh," and in some words even to "th."

There is no need to enter here into the host of fancy names by which the gramophone is known; but it may be interesting to give a little information on one of its most promising applications, namely, the Gaumont chronophone, which is a highly ingenious combination of the cinematograph and the gramophone, arranged to run in perfect unison. Scenes from operas, character songs, and similar subjects can be thus shown as animated pictures on the screen; the music and singing being meanwhile heard, following exactly the movements of the singer's lips and the accompanying action. The apparatus consists of a chrono-bioscope driven by a special type of electric motor. The gramophone is driven by a similar motor, both bioscope and gramophone being connected by a main switch with two-way contacts, enabling either of them to be used separately, or both concurrently in complete synchronism. The chronophone is regulated and worked from a switchboard.

CHAPTER II

Choosing a Talking Machine

PRIMARY points in choosing a talking machine are that the machine must be substantial and the motor smooth running. It has already been shown that sound is recorded and reproduced by vibration, but this vibration should be confined as far as possible to the drum-head or diaphragm itself. Tremors, such as are caused by a shaky or ill-balanced motor, or by a flimsy framework, confuse the sounds issuing from the trumpet, and to this fact is due the harsh and unpleasant tone of inferior instruments. Portability should be a secondary consideration to substantial construction. Other things being equal, a solidly-built machine will give both a more powerful and more refined tone than one of light make.

In choosing a machine, first examine the exterior fittings and general equipment. If moving or detachable parts are observed to be carelessly put together, so as to rattle when lightly shaken, the machine is best passed over. Test the turntable of the disc machine for side play; it should be rigid. The same remark applies to the mandrel of a phonograph. Now wind the motor fully, and allow it to run (without a record) at its normal speed, 75 revolutions per minute for the needle disc, 90 for those played with a sapphire ball-stylus, and 160 for all cylinder machines. Choose the instrument which makes the least audible and most regular humming. Place the finger-tips on any part of the frame or case and discard the machines which give evidence of tremor.

Correct motor speed is maintained by a governor built up of balls or weights (generally three in number) attached to springs; these operate a simple brakework, which regulates the running. If these balls are not of similar weight, or if their springs differ in temper or substance, the combination will not spin evenly, but will jump like an ill-mounted flywheel. The governor revolves fast, making from 800 to 1,500 revolutions per minute, and the smallest error of balance is magnified to a vigorous rippling tremor at this speed, causing either a general harshness of tone or imparting an irritating tremolo to the reproductions.

Re-wind the machine and place a new record in position, adjust the sound-box or reproducer, and play the selection through. Now, at some little distance from, and not quite opposite to, the trumpet mouth, observe if the general effect is musical and pleasing, loud and full without being harsh; that there is no rippling or pulsation of sound; that the whole range of tone is free from sharp harmonics, metallic clangour, or small incidental discord. A well-known expert considers that "a solid tone" is evidence of good reproduction. The aptness of the phrase will become evident to those who listen to several machines in succession; one of them is almost certain to show superiority over the others in this respect.

Gramophones usually have an efficient horn, but no fair test of a phonograph can be made without the use of a large, suspended trumpet. The small ones sold with the machines are too short and commonly of a shape that is quite unsuited for the full development of the instrument's powers.

It is well to test machines with dissimilar records: one (say a violin solo) of small volume and interspersed with delicate *pianissimo* passages, and another of an elaborately orchestrated selection, full of broad, *forte* effects by the trombones and other heavy brass. A machine rendering both these extremes of volume pleasantly can be safely trusted. But during the playing note carefully that there is no tendency to flatness from end to end of the record. Recurrent falling off to flatness (and the subsequent recovery of pitch) is a common defect in cheap machines. This indicates an ill-cut or bent wheel in one of the slower-moving gears; or that the mainspring is badly set and binds against the drum or framework in places. A steady decline of pitch towards the conclusion of the record is proof of a weak or otherwise defective spring.

As the question of price materially concerns some of the suggestions that are to follow, it is best considered at this point.

Simple disc machines of reliable brands may be purchased at about 50s.; these will run one 10-in. and probably two 7-in records to each winding. More elaborate ones, of foreign make, running two or more 10-in. records, command about the same price. Inferior machines are advertised at £1 or less, but too much must not be expected of them. A first-class 12-in. instrument (English) may be had from £4 10s. upwards.

Phonographs are cheaper; well-known makes sell from £1 1s. upwards. At £2 2s. a wide selection of substantially built, smoothly-running machines is available. The choice includes the Edison and Edison Bell brands, heavy, rigid, and well designed. The German group of side-motor instruments (generally styled the "Excelsior" type) is similarly priced; these as a whole are excellent. The substantial and sweetly-running motors have a continuous wind, solid but light reproducers of aluminium alloy are provided, and the general finish leaves little to be desired. A totally distinct type, of lighter construction but even better wheel-work, is supplied by France, led by the house of Messrs. Pathé Frères.

Broadly stated, there is little to choose in the performance of a good two-guinea machine of the Edison, Pathé, or Excelsior types respectively. The Edison reproducer is a special feature, and is distinct from all others. Its diaphragm (of three-ply mica) is somewhat smaller than the average disc used in the "floating" reproducers of other machines, and the vibrations of the record exert a tractile or pulling effort on the drum-head instead of a compressive or hammering one. By this system, and the peculiar shape and setting of the stylus, it is claimed that this diaphragm "speaks" with greater distinctness (if less power) than others. Here, however, individual opinions differ.

The "floating" reproducers, common to ordinary machines, being of simpler construction, are more readily adjusted or repaired by the novice. On machines of French make, these are generally cast or stamped out of a composition, resembling papier mâché, which gives good results; but the substantial German reproducers of aluminium alloy yield a remarkably "solid" and satisfactory tone. Floating reproducers will not fit Edison machines except in combination with a special attachment.

Except in the case of very inexpensive machines, the silent and continuous-winding action should be insisted on. By this arrangement the key revolves almost noiselessly in the running direction of the great wheel, and consequently the machine may be wound up while it is playing. This makes a large and elaborate motor unnecessary; the cost of a machine capable of running half a dozen or more records to the wind is very much higher than one designed to operate two as a maximum. Large machines do not necessarily play better or more powerfully than well-made small ones, the only advantage of the former being the longer run and proportionately longer wind, though, of course, substantiality counts for something. In any case an operator must be in attendance to change the records, renew needles, etc., and while doing so he will acquire the habit of giving a few turns to the key almost involuntarily; thus the machine is practically at full power continuously, and a run-down need never occur. Motors having a reversed wind are common among cheap instruments. These must be stopped and wound fully after each selection.

Among the cheapest phonographs, costing but a few shillings each, the "Puck" type, being simple in design, is one of the most trustworthy. The motor, trumpet, etc., are mounted on a lyre-shaped casting having three short legs, one of which is adjustable as to height. The machines are for the most part of German manufacture, and are imported and sold in immense numbers. The batches vary greatly in quality (irrespective of retail price), and therefore the greatest care should be exercised in selection. If a good machine is picked out it will be found to afford more satisfaction than many more elaborate ones. There is very little to get out of order, and, if carefully used, the motor will run for years. A large horn may be adapted in the manner described in a later chapter.

Machines of obscure make and costing less than a guinea need to be closely examined and thoroughly tested before purchasing.

CHAPTER III

Lubrication, Speed Regulation, etc.

Before use, the new machine and its motor must be dusted and freed from packing, fragments, etc. Next lubricate the whole of the wheelwork with a smoothly mixed paste of pure graphite (plumbago or blacklead) and unscented vaseline. Force this into all bearings and the cog teeth with a wooden spatula. If the motor is enclosed, the grease cannot be too liberally applied; but exposed wheelwork should be freed from unsightly smears. This mixture never clogs nor becomes sticky; it not only prevents over-rapid wear, but its thick consistency much subdues any humming that may be excessive in the fast-running wheels and pinions, if worn or ill-cut. One thorough dressing will last many months if occasionally a few drops of good machine oil are sparingly applied. Price's cycle oil, the heavy B quality, or "Axeline," is suitable. After greasing, wind the action and run it down once or twice to distribute the lubricant.

The top-gear and guide-rods (if any) of a phonograph are best sparingly oiled with plain "Axeline" or vaseline.

The moving sockets of the reproducer and carriage attachment of a phonograph, and the tone-arm and trumpet-joints of a gramophone, should be smeared with unscented vaseline, the surplus being wiped off when the parts are reassembled. This not only frees the movements of these connections, but arrests vibration and renders them "sound-tight."

Before using a record, thoroughly clean up the machine, removing all superfluous oil. It will be well also to wash the hands. Records, particularly cylinders, are damaged by contact with grease.

The importance of speed regulation should be better appreciated than it is. Mechanical indicators are provided on elaborate machines; but these, even when reliable (which is seldom the case), are a superfluity. It is easy to determine the correct speed after a little experience. In a majority of cases records are run too fast. This has the effect of augmenting the sound; but it also raises the pitch, not only to sharpness, but often to the extent of several tones.

The novice should, in the first place, count the revolutions of his machine in order to accustom himself to what is required, what to expect, from records. Slovenly habits as to speed adjustment are readily acquired. Insensibly the ear becomes dulled to the subtle distinctions of fast, slow, and correct renderings, although errors will be painfully obvious to a critical audience.

The operator should periodically verify the pitch of his machine, adjusting its speed by any of the following methods: (1) Attach a piece of stamp-paper to the disc or cylinder, and check its revolutions by the seconds-hand of a watch; or (2) lightly scribe a straight line with a sharp instrument on a disused record (longitudinally on a cylinder or radially on a disc); run this on the machine with the reproducer or sound-box in position. The scribed line will produce a distinct tap at every revolution; check the tapping by the watch. It is unnecessary to test the full minute after a little practice. Let the cylinder (running at 160 revolutions per minute) emit forty taps in fifteen seconds. The Pathé type (or phonograph-cut) disc, at 90 revolutions per minute, makes thirty taps in twenty seconds. Needle-operated discs, at 75 revolutions per minute, should tick off twenty-five in twenty seconds. (3) The pitch of one sustained note in any record being known, it may be brought into unison with a tuning-fork or pitch-pipe.

The screw-head controlling the governor is too often in an exposed position on the machine, and therefore liable to alteration. Some simple means of fixing it should be devised, such as a lock-nut, or by causing it to move quite stiffly.

CHAPTER IV

Reproducers, Sound-boxes, or "Speakers"

THE diaphragm of a talking machine is essentially the source of its voice. The minute inequalities in the track of the swiftly running record provide the energy that throws the thin and resilient membrane (the "drum-head") into infinitely rapid vibration; the contiguous air is necessarily set in rippling disturbance, and so the impression of sound is conveyed to the ear.

Diaphragms are commonly circular in form, but not necessarily so. Any thin and elastic solid substance will reproduce sound from a record, but glass, mica, carbon, and hardened metal are in general use, the two first mentioned being the most commonly employed. Recently, claims have been made for the superiority of elephant ivory (thin sections cut from the best part of the tusk), but the material does not seem to possess any special virtue.

Discs cut from hard-rolled visiting or playing cards will reproduce sound quite tolerably for a time, but the millboard soon "tires," and by the loosening of its fibres becomes sluggish of movement, emitting an increasingly muffled tone. In degree the same remark applies to many other substances—hard wood, celluloid, vulcanite, etc. Mica tires in time, and, incredible as it may seem, so does hard metal, carbon, and glass.

After several months of constant use it is advisable to replace diaphragms. The owner of a machine may become so accustomed to the gradual deterioration of a diaphragm that he may not notice it has lost tone, although he will be immediately aware of the superior brilliancy of a new disc. Glass is probably the most enduring substance, but a season's wear is all that should be expected of it.

Common glass discs, as usually stocked by small dealers, are often too thin and flimsy to give a solid and brilliant tone. An average parcel will, however, be found to vary in substance, and only the stouter ones should be selected. A glass of 1½ in. to 1¾ in. in diameter should not be thinner than a light visiting-card, and those of 2 in. and upwards must be proportionately thicker. This remark applies also to mica and carbon discs, although these are more often of correct weight.

A too flexible diaphragm not only plays feebly, but it blasts in the forte passages with intolerable results. Blasting and general dissonance, from good records on a smoothly running machine, is mostly attributable to a flimsy diaphragm. Such a defect is readily detected by examination of the speaker, which should be held in a manner to reflect the light from its disc. The thumb-nail should now be lightly pressed on the stylus; there should be but little spring in the disc. If the latter is "soft," and readily compressed to concavity, it should be at once discarded and replaced by a stouter one. Such a change will be found to greatly improve at once the power and the quality of the tone.

Setting a diaphragm is a simple operation, but it is too often mismanaged. The phonograph reproducer will first be taken. Soak off the old disc and rubber band, and see that the latter is not perished or hardened by age; it should be quite pliant. Wash it and the cell free from all adhesive, and dry them thoroughly. Now lay the rubber ring on a clean surface, and apply, very sparingly, an even coat of Seccotine or similar adhesive. Place the ring evenly within the cell and press it down all round, using a disc of stout cardboard to compress it; allow half an hour's setting, and then wipe off all superfluous gum with a clean rag or sponge moistened in hot water. Dry off completely, and treat the flat of the band with the least possible quantity of cement evenly applied. Before this sets, place the glass (previously cleaned) in a truly central position, and press it into close contact with the rubber, not allowing the diaphragm to touch the rim of the cell at any point. Lay the reproducer horizontally, place the cardboard disc on the glass, and put the whole under light pressure in a dry situation until set. Afterwards sponge off all smears of gum from the disc and its edges, dry off, and mount the stylus dome, or spider, in the manner described on page 36.

Modern disc sound-boxes vary in design; among the simpler ones are those into which the diaphragm is inserted from the front, it being backed and faced by stout rubber rings. In more elaborate patterns it is necessary to unscrew the parts to change their discs. Regarding the former there is little to be said except that due care must be taken to seat the mica evenly, and keep it from contact with the cell. The better quality of speaker must, however, be dismounted, and, as typical of its kind, the "Exhibition" sound-box of the Gramophone Company will be taken as an example.

Remove the three screws from the rim and detach the flange from the body. Unscrew the small central diaphragm stud, being careful not to lose its back-nut. Now push out the old diaphragm and rubber gaskets; the latter are, in this case, small-bore tubes, and if these are found to have lost their elasticity, they must be renewed. The company supplies spare gaskets, cut to exact length and scarfed at the ends, to make a close fit within the cell. Similar tubing cannot readily be procured elsewhere. Cut the rubber, fit both lengths accurately, and insert the new diaphragm (of stout, clear, and unsplit mica), set it centrally on the front gasket, and back up with the other. Some operators prefer to attach the disc to the front rubber by a trace of Seccotine, to avert the possibility of its coming in contact with the cell while screwing the latter together; but it is best to employ no adhesive with this type of speaker.

Now secure the diaphragm finger to the disc by its central screw and nut, and melt a fragment of hard beeswax into the joint by the touch of a hot wire. Carefully reassemble the rim and body of the fitting with its three screws. The diaphragm should then be found evenly nipped between the compressed gaskets.

In a good light examine the face of the disc, and observe that it is not subjected to any strain. Move the needle-bar gently to test this. If the mica shows convexity or concavity, the tension screws must be carefully adjusted until the disc lies flat, its set being determined by its own elasticity. Unless absolutely necessary, any alteration of the tension screws should be avoided. If, however, they must be adjusted, be sure to slacken one to an equal extent with the tightening of the other; half a turn of each screw makes a considerable difference in the set of the finger end, and a complete re-tuning of the speaker would give some trouble.

Fig. 1 presents part of an " Exhibition " sound-box in plan and side section; the latter shows the diaphragm nipped between the compressed gaskets and insulated by them from the metal of the cell. The gaskets appear in solid black ; the bulging of their sectional outlines suggests the effect of the pressure of the flange and body of the box when screwed together. Fig. 2 shows in plan and section a phonograph reproducer of the floating type. The diaphragm (not touching the walls of the cell) is correctly mounted on its pliant rubber ring, which is drawn in solid black in the section (see also page 42).

In the Edison type of reproducer the diaphragm is not cemented; it rests on a narrow rubber ring, and is backed by another. On this is laid a thin metal washer, and a screwed ring clamps all together. The diaphragms in use are either of three-ply mica or hardened bronze alloy, the metal discs being stiffened by raised annular rings.

Some years since very large diaphragms were used on the cylinder machine, but exhaustive experiment has proved that any diameter above 2½ in. is unsatisfactory, unless the impulses of the record are reinforced, as with the Columbia sound magnifier, by a frictional relay system

A 2¼-in. diaphragm undoubtedly emits a more mellow and more powerful tone than a 1½-in. disc in the bass and middle compass, but there is a loss in the treble. In extreme cases very high notes are either seriously muted or altogether lost, because of the slower movement of the large disc. To overcome this defect an ingenious device (see Fig. 3) was invented by Mr. Henry Seymour. The Seymour double-disc phonograph reproducer is made up of one large diaphragm, 2¼ in. in diameter, mounted on a rubber ring cemented to the cell in the ordinary way, and on this is set a smaller disc 1½ in. in diameter, a rubber ring separating the two glasses, talcs or carbons. There is consequently an air space between the two (see Fig. 3). The smaller disc and gasket carry the dome and stylus. There is no advantage in the employment of two discs unless the larger one exceeds 2 in. in diameter. The slightest crack in either diaphragm destroys the resonance of both. The combined effect is very satisfactory; the power of the large disc is retained, and the smaller one provides brilliancy in the treble compass.

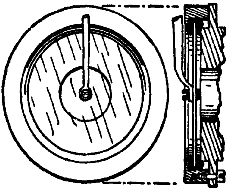

Fig. 1.—"Exhibition" Sound-box.

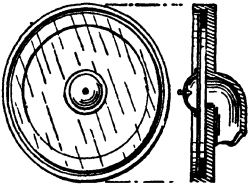

Fig. 2.—Floating-type Reproducer.

The qualities of the several substances used for diaphragms may be summarised as follows:

Mica, or talcum, yields a powerful tone, somewhat inclined to harshness; but it deals satisfactorily with a wide range of compass, retains its musical qualities well, and is practically unbreakable. It is in almost exclusive use on disc machines. This material is procurable at any large ironmonger's in small sheets at a few pence each. Select a stout sample, clear and free from laminations.

The best method of cutting discs is to mount the mica sheet (with beeswax) on a faceplate, run the lathe fast, bore the central hole $\frac{1}{64}$ in., and part out the disc with a keen tool of acute angle; the soft-soap-and-oil mixture, or even plain water, may be used as a lubricant with advantage. Mica may also be cut with strong, sharp scissors. Do not attempt to cut the circle from the sheet at one operation, or this laminated material will split badly along the line of cleavage. First shear off a square, find its centre by drawing diagonals, bore the central hole, then strike the circle with dividers, and snip gradually to shape.

Glass plays with extreme brilliancy; although its tone has been described as crisp, it is not wanting in refinement, a quality sometimes lacking in mica. Its disadvantage is its extreme fragility.

Carbon (probably by reason of its porosity and coarser structure) affords a pleasingly mellow tone. It reproduces vocal selections with singular fidelity and sweetness, and also appears especially adapted to the rendering of records of 'cello and violin music and that of wood wind instruments. It does not soon deteriorate, but of course it is fragile.

Ivory in tone closely resembles carbon; it is not so readily damaged, but its cost is at least ten times that of the latter.

Metals, such as hardened copper, bronze, bell-metal, etc., and flint-hard steel, all yield tones resembling that of glass without its characteristic brilliancy. Steel most nearly approaches this, but it does not long retain its resiliency; its brittleness is only second to that of glass or carbon.

Bone, celluloid, shellac, ebonite, wood, millboard, etc., are all second-rate substances for this purpose; their tone is wanting in crispness, compass, and durability in degree.

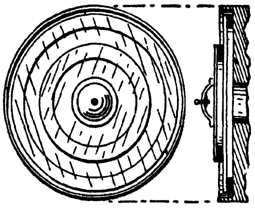

Fig. 3.—"Seymour" Reproducer.

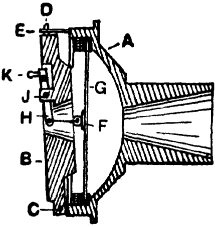

Fig. 4.—Edison B Reproducer.

In Fig. 4 above is shown the Edison B reproducer, with all parts lettered for reference. A is the body, B the weight hinged to the body by the pin C and prevented from falling too far open by the limit pin D, which is confined by the loop or staple E. The eye, or crosshead F is cemented to the centre of the diaphragm G; this is connected by a wire, or gut, link to the stylus-bar H, pivoted at J and provided with a sapphire ball-stylus K at its opposite end. There is perfectly free movement of the weight B on the hinge-pin C, and also of the stylus-bar H upon the fulcrum J. These two movements combined accommodate the stylus to the inequalities of the record. The diaphragm G is attached as follows: A narrow rubber band, or gasket, is first placed in the cell, then the diaphragm, then another rubber band, then a thin metal washer, furnished with a stop to prevent it revolving when the front ring is screwed in, to secure all in place and to nip the diaphragm between the gaskets. In Fig. 4 the rubber bands and washer are shown in solid black, and the screw-ring in cross-hatching. The B reproducer is now obsolete.

The Edison C reproducer (Fig. 5) is very similar to the B type above described, but a three-ply mica diaphragm is used instead of one of glass or sheet copper. A fantail weight A replaces the circular form of the B type. The stylus lever is hinged as shown, and a button-stylus B is set horizontally in it in place of the vertical ball-point of the older type (see also Chapter V.).

The owner of a B pattern phonograph reproducer may desire to alter it to give results equal to model C. This is not easily done, and, instead of attempting it, it is better to adapt a floating or graphophone type of reproducer to the phonograph. This may be most simply accomplished by removing the speaker arm from the machine (by slacking off the guide-bar screws) and using a large horn, with floating reproducer attached direct, the horn being pivoted as explained in Chapter IX.

Beginners often are led to ask whether the fitting of an extra large diaphragm to a machine would increase the volume of sound. Of course, enlarging the diaphragm (within reasonable limits) not only tends to the greatly improved reproduction of new and perfect records, but also those that are much worn may be rendered tolerable by the use of a "spider" of wide straddle, or a large dome. The effect of this is to subdue, and somewhat muffle, the vibrations, thus eliminating much of the harshness due to wear. The larger the diaphragm, the heavier would be the sound-box to contain it, and a heavy box wears away the records more speedily than a light box. If, however, the extra weight is compensated for by adding a balance weight so that the actual weight on the record is no heavier than before, a great improvement in the tone can be secured.

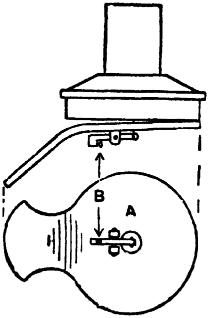

Fig. 5.—Edison C Reproducer.

Auxeto Pneumatic "Reproducer" for Gramophones.—The principle on which the Auxeto gramophone reproduces the sound wave does not involve the use of a diaphragm, as that term is generally understood in talking-machine practice. The original invention consists of an ingenious adaptation of the principles of the siren, and it may be considered a purely pneumatic device. The reproducer (which in this case is not accurately described as a sound-box) is in part a compressed-air chamber, supplied, by any convenient means, with filtered air at a suitable pressure. The inventor has found 3 lb. per square inch satisfactory for the type of valve he prefers (among several similar designs), and which he identifies as "No. 1, Class 1."

Figs. 6 and 7 give an outline sketch of a pneumatic reproducer. A is an air-tight, shallow, cylindrical box of cubic content not exceeding 3 in., supplied with air at a given constant pressure on one of its sides; on the opposite side is a means of egress by way of a fine grating B, having on the side of least pressure a machined face; opposed to the grating, and seated on the machined face, is a gridiron C of the same pitch; each bar of the gridiron C is arranged to cover one slot of the grating. The gridiron's lower extension terminates in a stylus holder D carrying the stylus, which rests in the record groove. This grid, comb, or group of reeds is pivoted on short, flat springs at a point midway between the stylus point and the terminals of the grid bars. The bars are cut an infinitesimal shade narrower than the width of the slots, so that, when grid and grating are closely superimposed, a very small volume of air may yet escape; but when they are separated, by movements imparted to the valve by way of the stylus holder from the record, the compressed air finds egress, in greater or less volume, into the apex of the horn, which is flanged and seated air-tight on the valve face, but for a narrow slot which permits the working of the grid stem terminating in the stylus holder. This slot is cut to sufficient width only to accommodate the slight movement that is required, and consequently only a very small proportion of the air escaping from the pressure chamber into the trumpet is lost.

In Fig. 6, E is the trumpet or tone arm, F is a disc of wire gauze, and G a space packed with cotton-wool as an auxiliary filter.

The comb and grating, bars and slots, are of fine gauge; in 1903 the inventor had arrived at a standard of 66 to the inch, which gave a slot-width of $\frac{8}{1000}$ in.; the face of each tongue measuring a shade less, their depth tapering from $\frac{3}{200}$ in. at the roots to $\frac{3}{1000}$ in. at the tips. But it was foreseen that the limit of effectiveness might not be reached by the use of a slot gauge of 200 to the inch. In this apparatus, therefore, the sound wave is caused to impinge directly on a column of air constantly escaping by way of the trumpet, and without the interposition of any diaphragm. Thus, this invention as closely approximates to the mechanism of the vocal organs as the diaphragm of resilient material, hitherto employed in talking machines, resembles the auditory mechanism in animals; it being understood that, in the latter case, all vibratile conditions obtaining outside the horn are equivalent to those transmitted by the ear-drum to the brain.

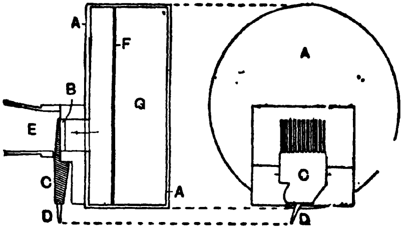

Fig. 6. Fig. 7.

Figs. 6 and 7.—Pneumatic Reproducer for Gramophone.

Tone Arm.—A tone arm such as that shown in

Fig. 8 has been adapted to a 10-in. Odeon, with the result that the machine is brought completely up to date, and is available for use with any modern sound-box that is adapted for the gramophone groove (such as that described in Chapter VI.), and also for the new-style discs of phonograph cut, for use with the sapphire ball-stylus. The fitting must not be made for trade purposes, the design being the property of the Gramophone and Typewriter Company. The rigid, swinging, tapered arm shown carries the ∩-shaped, hinged tone arm. The improved tone resulting from the use of this fitting is undeniable, apart from the convenient manner in which the sound-box may be swung upwards and backwards while adjusting discs and needles.

The ∩ may be of ¾-in. seamless brass or copper tube of medium gauge; this must be first annealed by heating to redness and quenching in water, and afterwards filled with lead and carefully bent over mandrels, bringing the ends within about 2½ in. of each other, centre to centre. Not less than 12 in. or 18 in. of tube should be treated, as a shorter piece will not afford enough purchase in handling. Avoid mutilating the tube and cockling the inner side of the bend. When the tube is bent, melt out the lead and cut the tube to the correct size. Portions of the tube that remain over may be enlarged by beating on a mandrel, and utilised for the right angle of the tapered arm sleeve A, and a ¼-in. cutting will serve for the shoulder of the ∩ (see B, Fig. 8). The open end at C is closed by a disc of brass, soldered in, with a ⅛-in. tapped hole in the centre to take the milled stud D. The illustration almost explains itself.

The tapered arm may be butt-jointed, or lapped and soldered, of sheet brass or copper, $\frac{1}{32}$ in. thick or less. The cylindrical part at the larger end E makes a stiff sliding fit on the outside of the swinging elbow, the original tone arm and pivot being removed. The taper is from $\frac{3}{4}$ in., full, at the right-angle joint to the diameter of the elbow, and the length of the cone is determined by assembling the ∩-piece, the sound-box, and the right-angle, or T-piece, on the turntable, and measuring up. The needle must reach the centre of the table. The cone may be set out first on paper by the usual arrangement of arcs and radii, as shown in Chapter XI., the general measurements of the plan being determined by multiplying the required diameters of the cone, at either end, by 3·14159.

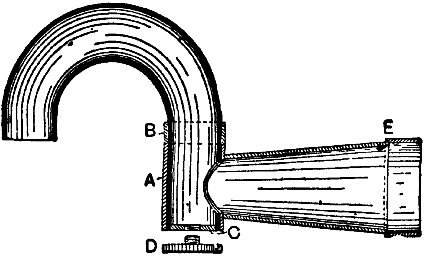

Fig. 8.—Tone Arm for Gramophone.

Columbia Sound-magnifier.—This device is not readily adaptable to an ordinary phonograph, as its construction entails additional gearing to operate revolving mechanism within the body of the reproducer itself. Few phonographs lend themselves to the necessary alterations and additions; however, the following brief description may be given. In Fig. 9, A represents the diaphragm, to the centre of which is attached the link B hinged at each end; this is connected to the shoe C, which resembles a two-part band brake extending more than halfway round the grooved pulley D, which revolves regularly in the direction indicated by the arrow. At the opposite termination of the jointed brake is hinged the link E, connected to the lever G, which is pivoted at F, and provided with a stylus at the other end. The sapphire is cemented to a hinged lever in a similar way to that of the Edison C reproducer. The diaphragm is of mica, 4 in. in diameter; the lever G is supported by the swinging frame which carries the disc, etc. Vibrations imparted by the record H are transmitted to the shoe C, which consequently exerts a rapidly varying braking effect on the pulley D. The pulley, however, maintains its speed, and the normal friction existing between the wheel and the brake is modified by the movements of the lever G, actuated by the stylus, and consequently the brake clings to, or releases

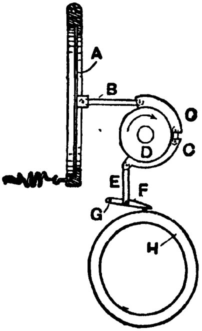

Fig. 9.—Sound-magnifying Device for Phonograph.

its hold on, the wheel in proportion to the varying tensions set up by the record. Hence the effort at the diaphragm will equal the rise and fall of the stylus, plus the torque of friction between the surfaces in contact. The pulley is usually of amber, and the shoe of stiff rubber, but other materials are available. Fig. 9 is, of course, diagrammatic only. The friction disc may be ¾ in. in diameter and ½ in. wide; it may revolve at eighty revolutions per minute (half the mandrel speed). It may be belted to, or cog-driven from, the mandrel gear by means of a telescopic tube having a lateral slot of length sufficient to permit extension to the required limit of the record. The spindle of the friction disc may be connected with the telescopic tube by a universal joint.

CHAPTER V

The Needle and the Stylus

IN the first place, it should be said that although certain brands of gramophone needles are advertised to be utilised for several discs in succession, it is unadvisable to use any needle twice. Really good discs are expensive, and the damage done by a single traverse of a worn or otherwise faulty needle point is irremediable.

The walls of the track of a needle-record are thin and fragile; the sinuosities of the groove, as the record spins rapidly under the weighted needle point, cause the latter to bear heavily against the walls. Both the needle and the track walls are constantly in a state of antagonistic stress. The wavy groove deflects the needle vigorously to right and left at almost inconceivable speed, the oscillations being most rapid on high-pitched notes. If these facts are considered, it will be admitted that the smoothest possible travel of the point in the groove is essential if the latter is to remain unworn for any considerable time.

A needle examined with a microscope after use shows facets on each side. Such wear cannot be entirely avoided; but if employed twice these facets will develop into ragged cutting edges, the extreme point will break away, and the record must immediately suffer by the tearing action of the needle, now become a scraping tool. In this connection observe that thorough dusting of the groove not only removes the sharp grit ever present in the air (particularly in dry weather), but also the impalpable but destructive powder of hard steel, ground from the last-used needle.

The Pathé and other **U**-groove discs are played with a ball-ended sapphire stylus, and the dot-and-dash record acts on this in an up-and-down direction instead of by side-to-side impulses given by the wavy **V**-track. The following remarks on the running of cylinders apply also to **U**-groove discs, the principle of reproduction being common to both.

Sapphire is only second to the diamond in hardness, and a ball or button made of it will play many hundreds of cylinders without becoming worn. Directly, however, its high polish is lost, it rapidly deteriorates, scraping and damaging the track more and more. Well-dusted wax-emulsion cylinders will last for many years if the reproducing point is renewed or reset at the very first sign of wear.

Fig. 10.—Button-stylus.

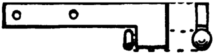

Fig. 11.—The Button-stylus Set.

The Edison type of reproducer has a button-stylus (Fig. 10), set as shown in Fig. 11; the lower edge fits into the **U**-shaped track. When after long use this portion becomes roughened, it is possible to turn the stone in its setting to present a new surface. To do this, the lever is removed from the body of the reproducer, and warmed sufficiently to soften the cement. The stone is gripped in small forceps and given a quarter turn. Deft manipulation will permit of this being done three times after the first surface has become roughened, thus giving four renewals, after which the sapphire may be discarded or returned to the makers for repolishing.

Ordinary reproducers for cylinders, and those employed on U-groove discs, have ball-styli as shown by Fig. 12. When these are set to trail slightly (relatively to the direction of the cylinder's revolution) a full half-turn will often suffice to present a new surface. In cases where the stylus is set upright (or radially) on the cylinder, no re-setting is possible, as the bottom of the ball rests in the groove, and when worn it must be renewed or repolished. (Glass points are serviceable for cylinders, and wear well; they are very cheap and easily fitted, and instructions how they may be made and set are given later.)

The styli of disc reproducers are commonly applied to the record at a considerable angle (see Fig. 13), and consequently one, and sometimes two re-settings are practicable. Discs, being of harder material, wear the sapphire faster than do wax cylinders; the ball presses more heavily on the groove, and in several ways the friction is greater than that obtaining in the phonograph. The condition of sapphire or glass reproducing points should be constantly observed, and at the first sign of wear they should receive attention.

The earliest indication of a roughened stylus is the defective reproduction of sound from good records. A slight harshness on high-pitched notes (or close harmonies), and a loss of robur in the bass, will manifest itself to the sensitive ear some time before the point becomes so defective as to cause damage to the records. If no remedial measures are taken at this stage, things rapidly go from bad to worse; the worn stylus soon begins to score and plough up the track, leaving a trail of torn fragments, the record assuming a whitish and scratched appearance. No after treatment can eradicate the harshness that ensues, although it may be modified to some extent by the application of graphite powder or french chalk to the disc or cylinder, and afterwards thoroughly brushing off the dry lubricant.

Glass styli are useless for discs, but serve well for phonographs fitted with floating reproducers. Their cheapness permits of constant renewal; but if records are always dusted, a glass point will last some months of occasional use.

Fig. 12.—Ball-stylus.

Fig. 13.—Angle of Ball-stylus to Record.

Fig. 14.—Glass Stylus in Reproducer Dome.

To renew a glass point, the dome or spider must be soaked off the diaphragm. This may take some time, the reproducer being levelled and a little water flowed round the dome. On removal, the latter is heated sufficiently to soften the shellac cement, and the old point is withdrawn. The new one being inserted in its place, heat is again applied and the stylus fused in. While cooling, a few deft touches with a piece of wire or a match stick will correct any sagging of the point and leave it standing straight in its setting as shown in Fig. 14. Care must be taken to keep the ball head free from cement. The dome may be re-attached to the diaphragm with Seccotine or hard beeswax; the latter facilitates removal when necessary. The least sufficient quantity of either substance should be used; if clogged with adhesive the elasticity of the diaphragm will be impaired, and it will emit a muffled tone.

The glass points themselves may easily be made after a little practice Enough thin glass rod or thermometer tube to make hundreds of styli can be bought for a few pence from a druggist. Take a piece about 6 in. long, and heat a couple of inches of the middle of the rod over a gas or spirit flame until quite softened (a dull red heat). Now remove from the flame, and pull the ends sharply but steadily apart; the glass will draw out into a fine, smooth thread of graduated diameter. When cool, select some lengths of suitable thickness (about $\frac{1}{64}$ in.), break them off, and proceed to roll up the ragged ends by fusing in the flame. To ensure the formation of neat bulbs, the lengths of drawn glass should be file-nicked and broken as neatly as possible. The extreme end is then approached to the margin of the flame and slowly revolved while it heats up, glows, and fuses. Keep the ball heads as small as possible, of the shape indicated in Fig. 12, and, when cool, file-nick off, say, $\frac{1}{4}$ in. long. Several dozen may be made in a quarter of an hour; 50 per cent. of them will probably be perfect, but each should be examined under a powerful magnifying glass, and any showing irregularity, bubbles, etc., should be thrown away.

To make sure that a new point does not scratch it should be run on an old record.

Constant renewal of styli, tidy manipulation, and scrupulous cleanliness, insure long life to records. A new cylinder, undusted or run under a defective stylus, may be spoilt by the first reproduction.

CHAPTER VI

Making a Gramophone Reproducer

THE details of the reproducer described in this chapter can be slightly varied to meet requirements, but the general design and dimensions should be adhered to, as the instrument is the product of much experiment. The whole of the work can be carried out with hand tools, but a slide-rest is desirable. The illustrations are reproduced full size.

The body (Figs. 15 to 17) and the ring (Figs. 18 to 20) are brass castings; the patterns must allow for shrinkage and machining. Mount the body on a face plate or in a recessed hardwood chuck, bore out the centre to $\frac{9}{16}$ in., and face up. Re-mount on a truly turned spindle, and finish both sides and rim to the dimensions as follows: Greater diameter, $2\frac{1}{16}$ in.; lesser diameter, $1\frac{1}{2}$ in.; thickness of latter, $\frac{3}{8}$ in.; thickness of central flange, $\frac{1}{8}$ in. Then scribe lightly a circle exactly 2 in. in diameter on the face of the flange. Next remove the body from the chuck, grip between lead jaws in the vice, and file the flat B (Fig. 15) to within $\frac{1}{8}$ in. of the lesser diameter. The holes indicated should be bored, the two at the back of the body at C (Fig. 15) to a depth of $\frac{1}{4}$ in., and tapped $\frac{1}{8}$-in. Whitworth (see Fig. 17), and the three, D, in the flange, $\frac{5}{64}$ in. clearing. The ring (Fig. 18) is a light casting, and is conveniently chucked in recessed hardwood and the face machined. Then reverse and tool out the recess E to $1\frac{3}{4}$ in. diameter and $\frac{1}{4}$ in. deep, leaving a flange which when finished is $\frac{1}{64}$ in. to $\frac{3}{32}$ in. thick, its inner diameter being $1\frac{5}{8}$ in.

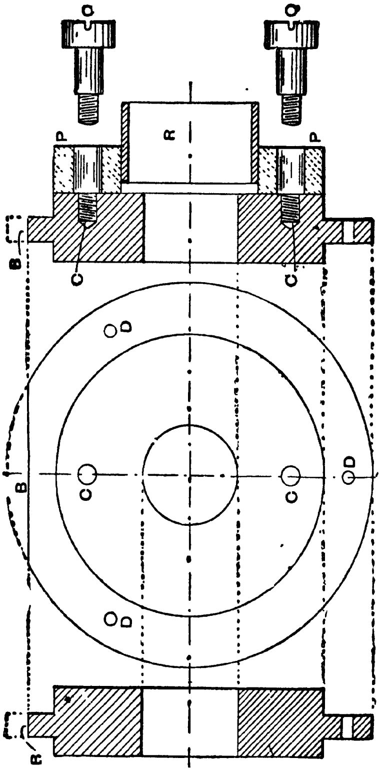

Fig. 17.

Fig. 15.

Fig. 16.

Figs. 15 to 17.—Plan and Sections of Gramophone Reproducer.

Re-chuck on a hardwood mandrel that fits the recess accurately, and turn the rim to 2 in. in diameter, its width being $\frac{1}{4}$ in. full to $\frac{9}{32}$ in. While still in the chuck, file the flat F (Fig. 18), leaving $\frac{1}{16}$ in. substance to the recess. Then remove from the chuck and hard-solder on the fitting G (Figs. 18 and 20), which is of $\frac{1}{16}$-in. brass, $\frac{7}{8}$ in. long, $\frac{1}{4}$ in. wide, and $\frac{3}{4}$ in. over the lugs. A plan and elevation of the fitting G is shown by Figs. 21 and 22. The small knife-edge projections H (Figs. 18 and 20) are $\frac{1}{8}$ in. wide and $\frac{1}{16}$ in. high. They can be formed in the material by filing or planing, in which case $\frac{1}{8}$-in. brass must be used; or they can be riveted into the $\frac{1}{16}$-in.

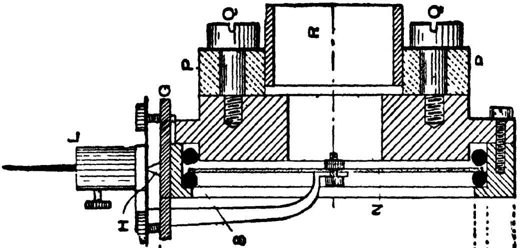

Fig. 20.—Part Section through Reproducer.

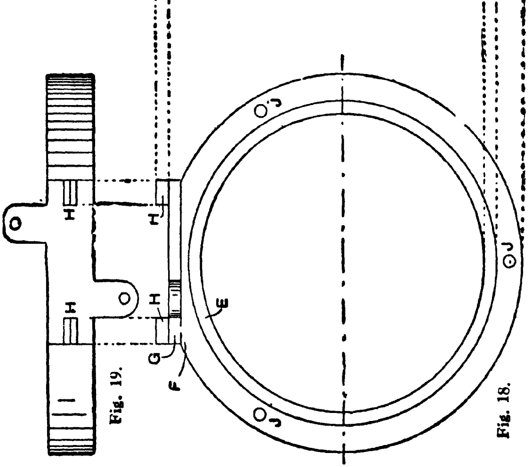

Fig. 19.

Fig. 18.

Fi 18 and 19.—Ring of Reproducer.

metal and trimmed up. The holes, tapped $\frac{3}{64}$ in., are spaced $\frac{3}{8}$ in. apart, in line with, and $\frac{5}{8}$ in. apart across, the ring. The body (Fig. 15) and the ring (Fig. 18) are now assembled by the scribed gauge circle and the screw holes D marked, bored, and tapped in the ring $\frac{3}{64}$ in. by $\frac{1}{8}$ in. deep as at J (Fig. 18).

The fitting, shown by Figs. 23 to 26, is next built up and hard-soldered together. The base, of $\frac{1}{16}$-in. brass, is $\frac{7}{8}$ in. long, $\frac{3}{16}$ in. wide, and $\frac{7}{16}$ in. over the central lug. It has a shallow saw-kerf centrally on its under side as at K (Fig. 23) to engage with the knife edges of the ring fitting G. The needle socket is of $\frac{1}{4}$-in. brass rod $\frac{3}{8}$ in. long, bored to suit the needle shank and tapped at the side $\frac{3}{64}$ in. for the set screw.

Fig. 21.

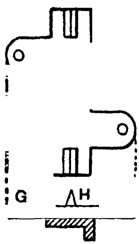

Fig. 22.

Figs. 21 and 22.—Ring Fitting.

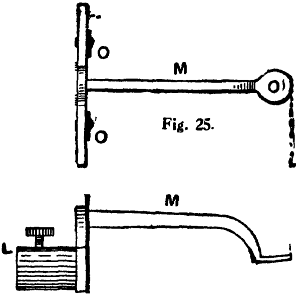

Fig. 26.

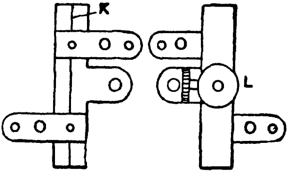

Fig. 23. Fig. 24.

Figs. 23 to 26.—Needle Fitting and Diaphragm Finger.

The diaphragm finger M (Figs. 25 and 26) is $1\frac{1}{16}$ in. long from the under side of the base to its central hole:

it is of $\frac{1}{16}$-in. brass, and tapers from $\frac{3}{16}$ in. to $\frac{1}{16}$ in. at its terminal disc, through which, and the talcum diaphragm N (Fig. 20), passes a small screw, nutted at the back of the diaphragm. Two pieces of steel, or hard brass, spring $\frac{1}{2}$ in. long by about $\frac{1}{8}$ in. wide, are riveted to the base, as shown at O (Figs. 23 to 26), equidistant from its centre and $\frac{3}{8}$ in. apart. In the ends $\frac{3}{64}$-in. holes are bored, to correspond with those in the ring plate G. When attached, these springs are bent equally towards the needle socket L, so that when the screws are passed through them, an equal tension can be exerted on the diaphragm finger M.

A disc of rubber P (Figs. 17 and 20), $1\frac{1}{2}$ in. in diameter and $\frac{1}{4}$ in. thick, with a $\frac{3}{4}$-in. hole in its centre, is attached to the back of the body with two $\frac{1}{8}$-in. cheese-headed screws Q $\frac{1}{4}$ in. plain under the head. Into the central hole is cemented a $\frac{7}{16}$-in. length of brass tube R having a $\frac{11}{16}$-in. bore. This tube must not be in direct contact with the body, the object of the rubber being to insulate the vibrations of the sound-box from metallic connection with the tone-arm or trumpet.

Fig. 20, which is in part section, is intended to facilitate the assembling of the parts. Before this is done, the work should be polished and lacquered, or nickel-plated. First secure the rubber buffer P and the tube R to the back of the body (Fig. 15). Then loosely attach the finger fitting (Figs. 23 to 26) to the ring (Fig. 18).

Select a good mica disc N of $1\frac{11}{16}$-in. diameter, and bore a fine hole in its centre. Cut a length of $\frac{1}{8}$-in. rubber tube, with scarfed ends, to neatly fit the recess in the ring.

Lightly dress the edge of the diaphragm with adhesive, and place it on the rubber within the cell, working it carefully to a central seating, not touching the cell at any point. Apply light pressure and set aside to dry; do not stick the gasket to the flange. When set, fit a second rubber gasket to the back of the diaphragm, without adhesive, and assemble the body and the ring by the three screws to fit the holes D, when the two rubber rings S will evenly and closely grip the diaphragm N. For the sake of clearness, the rubber tube gaskets S are shown conventionally, in Fig. 20, as black circles. In practice, they will flatten under pressure, and spread considerably.

The finger fitting is now gradually screwed up, half a turn at a time on each side, until fairly rigid with the main body, the terminal disc just bearing on the diaphragm centre. The small screw is then passed through the finger end and diaphragm, and secured with a small flat nut at the back (see Fig. 20). A speck of hard wax can be melted into the joint to arrest possible vibration.

The sound-box is now complete, and will be found to weigh between 4 oz. and 5 oz., which is about correct for modern disc records. The tuning-up must be carefully attended to by actual trial on a machine, the tension screws being used for the purpose. Theoretically, the diaphragm should be submitted neither to much pressure nor tractive strain, its own elasticity determining its normal set.

If facilities for brazing and silver-soldering are not available, the joints can be made with soft-solder, using zinc chloride as a flux; but this is less satisfactory.

CHAPTER VII

Making a Floating Reproducer for a Phonograph

ANYONE possessing a phonograph fitted with the ordinary-size reproducer may improve the tone of his machine to a surprising degree, and at a small outlay, by following the instructions given in this chapter. With a lathe the work will be easily done, but results almost equally as good may be attained without its use by anyone who can handle the soldering bit, file, and other simple tools.

Figs. 27 to 29 show plan, end, and side elevations of a built-up reproducer. If preferred, a pattern could be made and the fitting cast complete. The material may be brass, zinc, or aluminium; the latter is very suitable owing to its lightness, but it is difficult to work and to solder. The body of the reproducer should be of the stoutest substance possible to the weight permissible; the maximum pressure of the point or stylus on the record should not exceed 1½ oz. Should brass be selected, procure a piece of sheet ($\frac{1}{16}$ in. to $\frac{3}{32}$ in. thick) from which a circle A (Fig. 27), 2½ in. in diameter, can be cut. Flatten carefully by hammering, scribe a circle of the size mentioned, and mark out the slot B B ¼ in. wide by 2 in. long. The slotted disc may be cut out with a fret saw or cold chisel, or by boring rows of holes closely together, and finishing by filing. The disc must be neatly made, and it must be absolutely flat, smooth, and free from hammer bruises. When finished, anneal by heating evenly over a clear fire or gas stove to a dull red, and quenching promptly in cold water. This is advisable because, if the metal has become hardened by rolling or beating, it will more readily vibrate upon certain tones, causing discord in combination with the normal vibrations of the diaphragm.

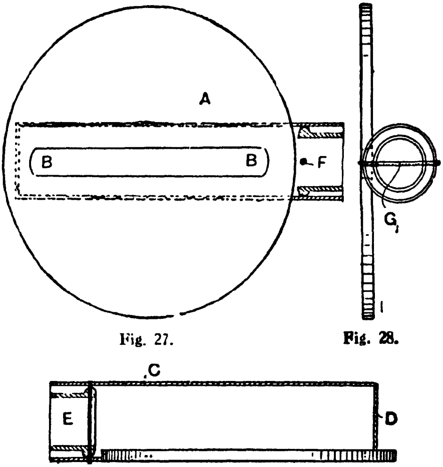

Fig. 27. Fig. 28.

Fig. 29.

Figs. 27 to 29.—Plan, End Elevation, and Side Elevation of Floating Reproducer for Phonograph.

When annealed, clean up and polish. Procure a piece of ⅝-in. brass tube C (Fig. 29), 2¾ in. long, and file away one-eighth of its diameter for a length of 2⅜ in., to make a true and even seating on the back of the disc. The remaining ⅜ in. of the tube is left cylindrical for attaching direct to the trumpet or to the swing fitting of the sliding carriage of the machine should there be one. Attach the fitted tube to the body with binding wire, and close the non-protruding end of the tube with a ⅝-in. disc of sheet brass D which has a ⅛-in. flat filed from its circumference to suit the part of the tube which has been filed away. Secure this also with a few turns of wire. Carefully dress all joints with soldering fluid (zinc chloride) and heat over a flame or with the blow-pipe. Again dress with fluid and place a few scraps of solder along the joints. Heat strongly until a neat and perfect joint results, then wash thoroughly.

If a direct attachment to the trumpet is preferred, the reproducer will now only require the diaphragm and dome to be attached to be complete. If, however, the machine has a sliding carriage, an inner tube to fit the machine must be pivoted within the main tube end. This is easily done. A ⅜-in. length of brass tube, making a snug fit to the carriage socket, is taken, and a stout brass ring slipped on and soldered. The ring is then filed to make an easy fit within the main tube as at E (Fig. 29). A hole F (Fig. 27) is bored through as shown, and a wire peg G fitted, allowing the reproducer to swing ⅛ in. or so, horizontally to each side.

A rubber band of suitable size is now attached to the face of the disc with Seccotine, and allowed to dry thoroughly under pressure. When dry, remove all superfluous adhesive with moisture, leaving the rubber soft and pliant. Apply rubber tyre solution to the band, and lightly work the glass diaphragm into a central position, avoiding air bubbles. Then place on a flat surface, and weight the back of the reproducer with an even pressure of a pound or two until set. The dome or spider is then centrally attached with Seccotine.

Domes and spiders are to be had for a few pence at any dealer's, but they can be easily made of thin copper, brass, or zinc. Beat a dome out of sheet copper (well annealed) with a round-paned hammer, trim up, and bore to receive the point. Scribe out a hexagon, or octagon, for the spider, cut out the "legs" with shears, finish with a small saw-file, bend to form with pliers, and bore centrally $\frac{1}{32}$ in. for the glass point.

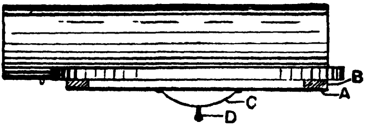

Fig. 30.—Sound-box of Floating Reproducer for Phonograph.

The largest reliable diaphragms the writer has yet been able to procure are about 2⅜ in. in diameter, but 2¼ in. will serve if the larger size cannot be obtained. The thickest of a batch should be selected.

This reproducer, in combination with a large trumpet, will be found most satisfactory, rendering every record not only with a minimum of vibration but with largely increased volume and tone.

Glass reproducer discs are procurable at most dealers in phonographs, but it is difficult to obtain them of sufficient thickness, particularly in the larger sizes, to give the best results. Thin glasses play harshly, and "blast" when used upon deeply cut or full-volumed records. In ordering from such a firm as Pathé Frères, explain that a glass 2¼ in. to 2⅜ in. in diameter is required (price 1s. or 1s. 6d.). Fig. 30 gives an idea of the construction of the sound-box. The diaphragm A is a disc of thin glass, talcum, carbon, metal, or other suitable material, mounted on a ring of pliant rubber B (an ordinary flat rubber band, say 2⅜ in. in diameter, ⅛ in. to ¼ in. wide, and 1⁄16 in. thick), and attached to the face of the metal fitting as described. A metal dome or spider C, carrying the point, ball, or stylus D, of polished glass, spar, or precious stone, is cemented to the diaphragm.

To use a reproducer of the type described in this chapter on an Edison Gem machine, the carriage must be removed and a simple substitute devised of stout wire, or even of wood, to which a horn-stem can be attached The makers of the Seymour reproducer supply a cheap adapter for Edison machines, and the attachment is available for use with any other reproducer of the "floating" type. Or the carriage may be dispensed with and the reproducer attached direct to the horn, as in the Pathé and Puck machines, by which method very clear reproductions result.

CHAPTER VIII

A Speaker-arm for Phonographs

Owners of Edison phonographs often desire to test other and larger types of reproducers on their machines; but, owing to the peculiar construction of the top-gear and speaker-arm of this make, no other diaphragm but the Edison can be used without radical alteration.

To meet a constantly expressed wish for facilities to use the floating, or graphophone, types of reproducer and recorder, such as the Seymour, Pathé, Columbia, etc., there has been designed the arm that forms the subject of this chapter. The fitting will especially recommend itself to those possessing machines with the obsolete B reproducer, for by its use the old instrument will be modernised, to a large extent. There is the advantage, also, that no alteration to the machine itself is necessary, and the fitting may be exchanged for the Edison arm, and vice versa, in a few moments by loosening two screws. No special mechanical skill or tools are required, and the materials should cost 1s. or less. The illustrations in this chapter are to scale, and show the fitting adapted to the Gem machine. Slight modifications of measurement and design, which may be necessary for the more expensive grades of the Edison instrument, will readily suggest themselves.

First detach the speaker-arm from the machine by slacking off the clamping screws and removing the guide-bar. Procure a 2-in. length of brass tube to make a sliding fit on the guide-bar A (Figs. 31 and 32). If difficulty is experienced in selecting a tube to fit, get one of larger diameter, plug the ends, and bore to suit. Take a 1⅜-in. length of the same tube, and by careful filing saddle it on the sliding-piece at right angles, B. Next mount a ⅝-in. length of stout brass tube C, having a ⅝-in. bore, on the opposite end of the upright piece in a slightly slanting position, as shown. Also saddle a small piece of ⅜-in. brass rod on the top of the ⅝-in. tube at D, to be afterwards bored and tapped, ⅛-in. Whitworth, to take the clamping screw E.

Assemble the parts with fine iron binding-wire; dress the joints with soldering fluid (zinc chloride), heat up, again apply fluid, and place some fragments of solder on the seams. Then heat strongly until the solder flushes, making neat and strong joints; let it cool, and then wash and dry off. Next bore a hole through the upright tube, at F, to take a $\frac{3}{16}$-in. or ¼-in. brass rod, which may be screwed or soldered in. The rod may be 7¾ in. to 8 in. long, and must be bent as shown at G. When bent to shape, and tested for correctness, by mounting the arm on the guide-bar and clamping the bar in its place on the machine, two holes should be bored, at H and I, to take the rigid peg, which rests on the front guide when the arm is in playing position, and the lifting peg, which comes into use when the arm is raised. The lifting peg may be provided with a head as shown, or it may be a plain pin with a stop at either end to prevent it becoming detached. The rigid peg may be screwed, soldered, or driven firmly into the bar. Both pegs may be of ⅛-in. brass wire.

Procure a 1¾-in. or 2-in. length of clockspring K, about ¼ in. wide, or a piece of dress-steel will do. Soften one end, by heating and cooling slowly, sufficiently to allow two holes to be bored or punched in the positions shown, to take the two small mushroom-headed screws L. The half-nut M may be of lead, pewter, or even hardwood. To thread it, detach the feed-screw from the machine, lay it on a flat surface, such as the table edge, with the cog-wheel overhanging. Having neatly hollowed the block M, place it over the screw and exert pressure on it under a strip of wood; give a slight rolling motion to the screw for a few minutes, occasionally examining the cavity in the soft metal or hardwood, to ascertain when the thread has sufficiently impressed itself. Be careful not to bend the

Figs. 31 and 32.--Side and Back Elevation of Speaker-arm adapted to "Gem" Machine.

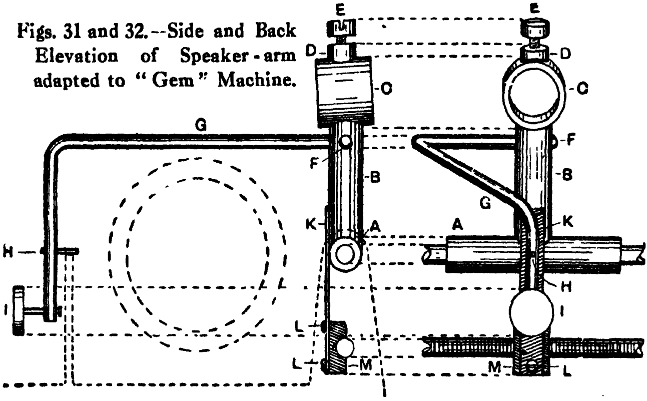

Fig. 31.

Fig. 32.

feed-screw; no damage will be done if it is rolled on a level hardwood surface. When threaded, bore two holes in the block, trim up, and attach to the spring by means of the two small wood screws.

Re-assemble the feed-screw, guide-bar, and arm on the machine, and mark the position of attachment for the spring to the upright and sliding parts of the arm. Then file a slight flat on the tubes to seat the spring, which may be secured with a couple of screws or solder. In the latter case, a hot, clean bit should be used, and care taken that other parts of the arm are not fused apart in the operation. Then mount again on the machine and adjust the tension of the nut-spring K by gradual bending, so that, when the peg H rests on the back guide, the half-nut M bears against the feed-screw with sufficient pressure to effectually traverse the arm or carriage, yet not so hard as to exert unnecessary braking effect on the motor.

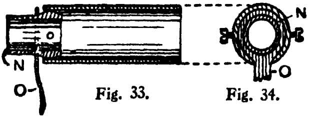

Fig. 33. Fig. 34.

Figs. 33 and 34.—Section and End View of Trumpet Stem.

Into the slanting tube or sleeve O may be clamped any of the ordinary graphophone or floating reproducer stems with moving socket; or the Seymour flexible attachment is a very convenient one. But, to complete the fitting, a 1¾-in. length of ⅝-in. (outside diameter) brass tube may be cut and fitted one end with a socket, as shown at N (Figs. 33 and 34). This may be constructed of two sizes of tube soldered together and filed up. If a lathe is available, it can be turned from the solid rod. The standard bore of modern reproducer stems is $\frac{7}{16}$ in., and the socket should be made that diameter. The moving portion may be connected to the stem by a plain, horizontal peg of $\frac{1}{32}$-in. wire; but a better arrangement is to mount the ball-socket on centre points engaged by two small set-screws, as in Fig. 34. Thus a very rigid, yet free, movement, without side shake is attained, which will be found of much advantage when a recorder is in use.

To the shoulder of the socket solder a strip of sheet brass O (Figs. 33 and 34), about 1 in. long, and bend this so that when the arm is lowered on the peg H, and the reproducer rests on the record in playing position, the brass strip is held about $\frac{1}{16}$ in. away from the upright tube B. When, however, the arm is raised and supported on the sliding peg I, the strip O will engage with the upright tube B, raising the reproducer, and at the same time, of course, the half-nut M will disengage from the feed-screw.

This fitting, being the writer's original design, and unpatented, may be made for commercial purposes.

CHAPTER IX

Horns or Trumpets

THERE is no reason to assume that conical horns or wide-flared trumpets (with or without curvature) are the best forms, but up to the present they have not been superseded. Some modern disc machines are hornless, in the sense that the amplifier is combined with the body of the cabinet containing the motor; but the principle involved is the same, the vibrating diaphragm being set at the apex of an expanding sound-duct.

The varying quality of sounds amplified by cones of different angle is remarkable, and too little attention appears to be given to this important fact by manufacturers. A fairly large horn of moderate taper, however, is desirable. Small and unsuitable horns, or wide-mouth trumpets of little length, reproduce fairly satisfactorily (one advantage of the wide flare being that the sound is well distributed); but undoubtedly the quality of the tone suffers in degree. In this particular the genuine gramophone has the advantage of most others, for whereas the horn in use may be similar in length and angle, the articulated tapering and ∩-shaped tone-arms considerably extend the (actual) length of the sound-duct as a whole, to the improvement of the tone. Anyone, however, who has tried a 56-in. suspended horn of narrow angle with the disc machine is impressed by its refining effect, even on harsh records.

Of course, the apex aperture must be larger than that for attachment to the phonograph; but this is easily arranged by cutting the trumpet at a point giving the required diameter for the stem of the disc machine, to which connection may be made with a short length of the inner tube of a cycle tyre. The cut portion may be fitted with a metal sleeve, soldered on, for re-attachment when desired, and thus the large horn becomes available for double service on cylinder or disc machines.

The "convolvulus," or flower horn, short and widely spreading, although it distributes sound well in small apartments, and its appearance is decorative, has tonal qualities undoubtedly inferior to the older type of plain, conical trumpet of narrower angle and moderate bell-flare. Just as the little zinc and aluminium trumpets sold with phonographs are incapable of doing full justice to the machine and records, so is the convolvulus horn unsuited to develop the best qualities of the gramophone. But it is quite possible to over-correct the fault in the opposite direction. A horn of too narrow angle is prone to muffle the reproduction, as well as to project it overmuch in one direction; and when a total length of about 5 ft. is exceeded, a phonograph horn begins rapidly to lose power without developing any corresponding advantage.

When buying or constructing a horn, a dimension both of length and diameter should be selected that lies midway between extremes.

As the result of numerous experiments extending over some years, the writer is of opinion that the length of a straight horn, between the limits of 2 ft. and 5 ft., is not of such material importance as the angle of expansion. In the case of the phonograph, this illusive angle appears determinable between a minimum of 10 degrees and a maximum of 15 degrees. Fig. 35 is the diagram of a horn having a 12 degrees taper. The solid lines *a* illustrate a 56-in. horn 11 in. wide at the mouth and having a 24-in.

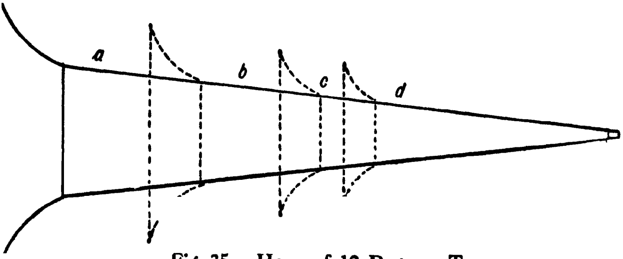

Fig. 35.—Horn of 12 Degrees Taper.

bell. The flares of shorter trumpets are dotted in for the purpose of comparison, and to show that the 12 degree angle is common to all. *b* is 42 in. long, 8½ in. at the mouth, and with an 18½-in. bell; *c* measures 30 in. by 6 in. by 14 in.; and *d* is 24 in. long, with an aperture of 5 in. and a flare of 12 in.

For reasons not obvious, disc machines may have horns of slightly more obtuse angle, which may vary between 15 degrees and 20 degrees; that shown in Fig. 36 expands at 18 degrees. Unless suspended, such a horn should not exceed 3 ft. in length (as drawn to scale), its mouth being 11½ in. and its bell 24 in. If larger, its weight might strain the machine when clamped on in the usual way, and this dimension gives admirable results. For use in a large hall, however, or out of doors, a suspended horn of the same angle, and relatively enlarged bell 5 ft. in length, will well repay its extra cost and inconvenient bulkiness.

Although the 56-in. horn of correct angle is generally admitted to develop the best qualities of any phonograph, it is undeniably a somewhat ponderous accessory, and in small apartments the 40-in., 36-in., or even 24-in. trumpet will fulfil each their requirements, according to the space available. A 24-in. length is quite the shortest permissible if records are to be rendered with tolerable fidelity; 30 in. is a useful size and fairly portable. There is but little to choose between the 42-in. and 56-in. horns in regard to volume of sound, but the latter refines and analyses complicated music to a marked degree, bringing out the individuality of separate instruments in the recording orchestra, and " humanising " the tone of vocal selections.

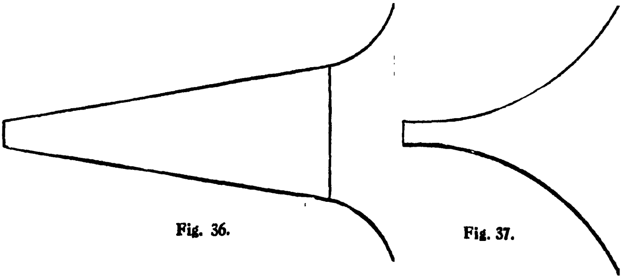

Fig. 36. Fig. 37.

Figs. 36 and 37.—Comparative Diagrams of Horns.

The primary importance of the expansion angle for amplifiers of reproduced sound having been proved by careful and eliminatory test, it is somewhat remarkable that imperfect forms of trumpet should be the rule rather than the exception. For the purpose of comparison, Fig. 37 shows the contours of a typical flower or herald horn commonly supplied with both types of machine. A glance at Fig. 36, proportioned on scientific lines, makes comment superfluous on the unsuitability of the convolvulus-shape horn, particularly if it is noted that the socket and flare are in each case identical.

Anyone possessing a phonograph with a guide-screw and reproducer carriage may attach a large horn without difficulty; but with the simpler machines, such as those of the "Puck" and "Democrat" designs, this, at first sight, might appear impracticable. A 36-in. horn, however, is readily attached to the cheapest machine, effecting a marked improvement in its performance. All that is necessary is to pivot the larger trumpet in the same manner as the existing one, but on a separate base, and to balance it so that the reproducer rests on the record with a similar pressure to that obtaining with the small horn. Fig. 38 shows the arrangement. If the trumpet-stand F (see also Fig. 39) and the phonograph P are set on a substantial support, and the cylinder is carefully levelled in the usual way, no run-off need be feared. Even should this occur, no harm will result, because the spur E is arranged to support the horn end when off the record.

Fig. 38 shows a home-made trumpet and stand, which can be constructed for about two shillings. Detailed instructions on making tinplate horns are given later; therefore only the plan and dimensions of this special trumpet need be given. The horn is cut from two sheets of light-gauge tinplate, 20 in. by 14 in., costing 5d. each. These are laid on the bench, as at A and B (Fig. 40), one overlapping the other 1½ in., and secured by a few drawing-pins round the edges. Find the centre of B, and at a distance of 2½ in. from its edge drive a nail or a bradawl into the bench; loop a cord to this with a sharply pointed scriber attached to the other extremity. Scribe an arc across A at a radius of 2 ft. 11½ in., and another of 1 ft. 10½ in. on B, and ⅜ in. within this yet another arc of 1 ft. 10⅛ in. Now temporarily remove B from the bench, and strike the 1 ft. 10⅛ in. arc also on A. Replace B exactly in position, and scribe on it the smallest arc, of 3-in. radius. Next, with a straightedge, draw in the converging lines.

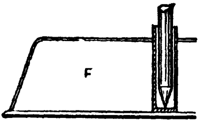

Fig. 39.—Horn Stand.

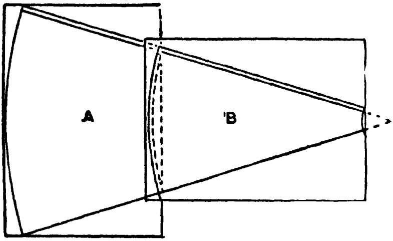

Fig. 40.—Pattern for 3-ft. Horn.

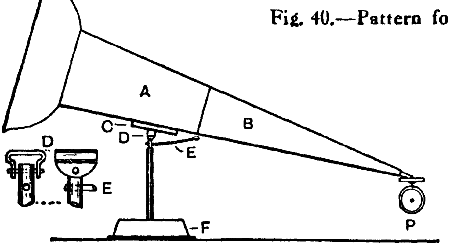

Fig. 38.—Home-made Horn and Stand for Phonograph.

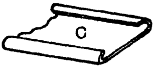

Fig. 41.—Fitting for Sliding Pivot Head.

The first of these is taken from the extreme upper edge of A, where the largest arc cuts it, to a point ⅜ in. above the centre point. The next line is parallel with the first and ⅜ in. distant from it; it terminates at the centre point. This is the gauge line, and the ⅜-in. space represents the lap of the seam. Draw in also the lowest line from the limit of the largest arc to the centre point. On removing B draw in the continuation of the limit and gauge lines on A, where B had overlapped.

Both limbs of the horn are then cut out, shaped, rolled, and soldered to the gauge line. They are then assembled by forcing the larger end of the cone B on the smaller end of A. If correctly cut, the former will make an accurate fit at the gauge line on the latter, and may then be soldered.

The flare or bell of the trumpet is a 14-in. tinplate hand-bowl, costing about 6d. A hole, slightly less than the diameter of the horn mouth, is cut out of the bottom, the horn is inserted and soldered from the outside, leaving ⅛ in. protruding within the bowl. This projection is afterwards neatly turned down into a seam and soldered. A piece of brass tube, of a bore to fit the reproducer stem and about 1½ in. long, is soldered into the small end of the horn.

The balance of the horn must now be found. First test the weight of the reproducer when attached to the small horn. The latter should be mounted on the machine with its reproducing point resting in the scale-pan of a small balance. Load the opposite pan and note the weight (which will be found to be ¾ oz. to 1 oz.). Now attach the reproducer to the large horn, rest the body of the latter on a knife-edge or other narrow surface, and move it to and fro until the reproducer balances the scale as with the small, original trumpet. Mark the point of balance, and afterwards solder on the fitting C midway across it. This fitting is a strip of stout tinplate or brass 4 in. long by 1½ in. wide; it is bent to form a slide, as shown to larger scale in Fig. 41. Within this, making a stiffly sliding fit, is the pivot head D (also shown enlarged). This surmounts the stem on which the trumpet is poised. This endlong movement permits the use of reproducers differing in weight, without unduly increasing or decreasing the pressure of the stylus on the record.

The horn stand F (Fig. 38) is a cake-tin about 7 in. in diameter and 1½ in. deep. A disc of tin is soldered just within the rim to form a bottom, and a brass tube, about 8 in. long and plugged at one end, is passed through the tin and soldered vertically (see enlarged part-section). Another tube or rod of brass makes an easy, but not shaky, fit within the larger tube; this is pointed at its lower end to reduce friction, and is capped by the fitting D. The base F (see also Fig. 39) may be weighted with shot, sand, or water, if desired; but it will be found to support the 36-in. horn quite steadily when empty.

The horn and stand should have three thin coats of enamel, each coat when dry to be rubbed down with pumice-powder and water. It is unnecessary to paint the interior of the horn, but the bell should be enamelled inside and out. A good body of hard enamel improves the tone of a tinned iron horn.

As regards the materials used for horns, *brass* has been largely employed. It imparts a somewhat metallic ring to all reproductions (particularly when the angle is incorrect), and, in addition to this, almost every horn of this substance has its particular harmonic, which resonates strongly when a synchronic vibration (the sympathetic note) is struck from the reproducer. This effect is sometimes displeasing, particularly in a vocal record, wherein certain tones of the singer may be rendered with a harsh, metallic twang. In powerful band selections the brass horn interprets well.

Copper, a softer and less resonant metal, yields similar results to the alloy without its harshness; harmonics are but little in evidence.

Iron and *tinned iron* are resonant without harshness. The tone is mellow and full; harmonics exist in iron horns, but they appear to "reply" far down in the bass compass, where their effect is negligible. The writer's opinion agrees with that of well-known experts, that enamelled iron or tinned iron horns yield the best all-round results at present obtainable from the record.

Wood, *wood-pulp*, and *millboard* have each their votaries, and the combination of a carbon diaphragm and a wooden horn is certainly admirable for vocal records, for wood-wind instruments, and for the 'cello. Wood horns are, however, very expensive, and it is questionable if their tone differs materially from that of stout millboard soaked in shellac varnish and thoroughly dried off.

Of *aluminium*, *zinc*, etc., little need be said; their tone is similar to copper, or midway between that metal and wood or pulp. Moderate resonance is desirable in a reproducing horn, but it must not be excessive. Non-resonant trumpets are adapted to recording, and are dealt with in a later chapter.

Making a 46-in. Tinplate Horn.—The performance of a phonograph is improved by the use of a large trumpet. A 56-in. horn of brass or copper, however, is necessarily expensive, anything between £1 1s. and £3 3s. being asked by retail dealers. The instructions about to be given show how an excellent tin-plate trumpet may be made at a cost of from 2s. 6d. to 7s. 6d. The writer has proved, as the result of many experiments, that a well-made horn of tinned iron yields a superior tone to those of brass or copper.

For a 46-in. horn (at a cost of 2s. 6d.), procure two sheets of light gauge tinned iron, size 2 ft. 1 in. by 1 ft. 5 in., which will cost 6d. each. Also a tinned bowl, 1 ft. 3 in. to 1 ft. 8 in. in diameter, costing from 6d. to 1s. Draw a line, lightly, with a sharp instrument, through the centre of each sheet; one in the direction of its length, and on the other across its width. Draw a straight line on the bench or table, and adjust the sheet, scribed across its width, at the further end, its centre line corresponding with the bench line. Secure with a few drawing-pins around the edges, and at a distance of 3 ft. 7¾ in. from the further edge of the sheet, drive a fine bradawl into the bench, on the line. Place a straightedge from one extreme corner of the sheet to the centre point, and scribe the angle deeply across the tin. Then place the straightedge at ⅜ in. within the opposite corner to the centre point.

and scribe. Parallel with this, mark another line, ⅜ in. outside the last; that is, from the extreme corner to ⅜ in. outside the centre point. Loop a piece of cord on the awl, stretch it, and at a distance of 3 ft. 7½ in. attach a sharp-pointed instrument. Holding this vertically, strike an arc across the tinplate, joining the straight lines previously made. Then remove the scribing point, and re-attach it 2 ft. 3¾ in. from the centre; strike the arc to the converging side lines, and make another arc ⅜ in. larger, or 2 ft. 4⅛ in. from the centre.

Then secure the second sheet on the table in the direction of its length and centrally, the top edge just overlapping the last arc made on the first sheet, and with the scriber at the same distance (2 ft. 4½ in.) strike the arc. With the straightedge continue the lines drawn on the first sheet, across the last attached sheet, towards the centre point, and continue the parallel line which falls ⅜ in. outside the centre. Also strike the smallest arc, which has a radius of 3½ in. (see Fig. 40). Then remove from the bench, and carefully cut out the two members of the horn on the scribed lines. Cut on the outer of the parallel lines; the inner line marks the lap of the seam.

The two sections should now be worked gradually into form, bending the edges first in a gentle sweep to the approximate curve. Roll up the cones, pulling and shaping until the edges meet and overlap evenly. A piece of scaffold pole held in the vice, or supported at each end, is useful in shaping the larger limb. Use the hammer or mallet as little as possible; rub the edges of the tin together with a piece of hardwood, or the hammer face, until they lie evenly. Bring the edge to the ⅜-in. guide line, and fix together in several places with a touch of solder. The seam can now be made, using a hot bit, plenty of soldering-fluid (zinc chloride), and a good run of solder. The section being supported from within, press heavily on it with the edge of a 6-in. length of board at the parts where the metal is running. The pressure should be maintained on each length under treatment until the solder has set. Leave no superfluous, lumpy patches of solder, but make a clean, close joint from end to end. Both sections being seamed, round up, and make cylindrical, by vigorous rubbing lengthwise on suitable mandrels. The apex of the cone may require truing up with a mallet, but use this tool as little as possible, to avoid unsightly bruising. Assemble the two members by slipping the larger end of the smaller cone outside the smaller end of the larger cone to the gauge mark, and solder.

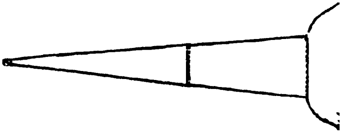

Fig. 42.—46-in. Horn.

Then strike a circle, slightly smaller than the trumpet-mouth, on the bottom of the bowl. Begin the cut with a tin-opener, and finish with shears. True up by light hammering, and finish with a smooth file. Slip the trumpet through the aperture and solder (outside), leaving ⅛ in. protruding within the bowl bottom. Work this outwards into a neat seam, and solder inside. The section (Fig. 42) shows the joints. Thoroughly wash the work in strong soda and water; polish the inside of the trumpet with whiting and water, and scour out the bell with coarse glass-paper for painting. Again thoroughly wash with clean water, dry, and heat up over a gas or paraffin stove. Then apply ordinary brunswick black to the outside of the work, beginning at the bell. A strong heat should be maintained, sufficient to make the enamel smoke, but not to melt the solder. When covered, keep up the heat for a time, and when cold, the surface should be bone-dry and should carry a high gloss free from brushmarks. The interior of the bell looks well enamelled red (three thin coats applied cold); or "fire-gold" paint, with a spirit base, is decorative and durable. This paint should be applied cold with a heavily charged camel-hair brush in wide sweeps. Do not go over the same place twice while wet. Two coats will suffice.

The rubber connection may be made direct to the trumpet end, or, if preferred, a piece of ⅝-in. or ¾-in. brass tube, 1½ in. long, can be soldered in before painting.

Making a 70-in. Tinplate Horn.—A 70-in. horn (at a cost of 7s. 6d.) presents greater difficulties than the foregoing, but it will repay the extra trouble, the tone produced being very fine. The writer believes this model to be unique in calibre, if not in length. The diagram should be carefully drawn out with tailor's pipeclay, or chalk, on the floor, or a table if large enough.

With the awl, string, and straightedge work out the measurements as follow (see Fig. 43): Radius of largest arc, 5 ft. 3¼ in.; second arc, 4 ft. 2¾ in.; third arc, 3 ft. 1½ in.; fourth arc, 1 ft. 7 in.; fifth arc, 6 in.; and sixth arc, 2½ in. With a long straightedge, draw in four equidistant radii from the outer arc to the centre-point. The extreme divergence of the outer radii, where they cut the arc,

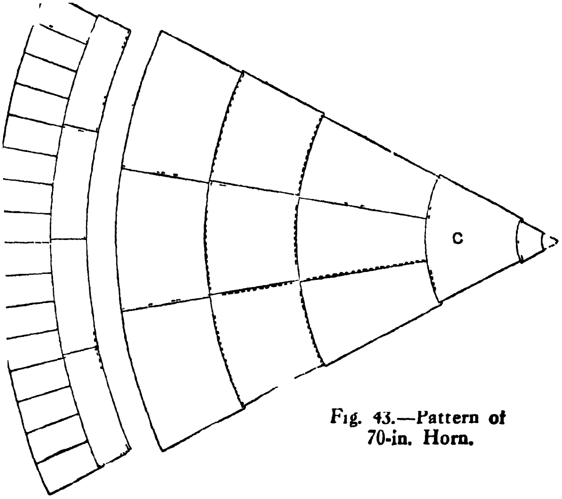

Fig. 43.—Pattern of 70-in. Horn.

g. 44.—Pattern of Flare.

must be 4 ft. 7¼ in., measuring directly across the latter rom point to point.

The metal is the same gauge as for the smaller horn, ut the 1-ft. 8-in. by 1-ft. 2-in. sheet (at 5d. per sheet) is more convenient size. The diagram being drawn out, hree sheets of tin, in succession, must be adjusted on the uter arc. Their arcs are then scribed on them, and the onverging lines drawn on each section, a ⅜-in. rebate eing provided in each case as before. The three sections forming the first limb have their rebates to the left, the next three sections to the right, and the third to the left. This will allow a neater joint at the junction of each limb.

Each set of three sections is first soldered together both sides on a flat surface, the seams being run while heavy pressure is maintained on them. They are then assembled (still in the flat state), and afterwards rolled, shaped, and soldered, as for the 46-in. horn. The combined members being cumbersome to handle alone at this stage, some assistance may be required.

The fourth limb is cut from one sheet (see C, Fig. 43), rolled, seamed, forced over the small end of the third limb to the gauge line, and soldered. The fifth cone reduces to ⅝ in., which is fitted with a short length of brass tube of the same diameter.

In this condition the horn will serve, but if desired, a flare can be added. This is shown in the flat state by Fig. 44, and rolled up, shaped, and mounted, at Figs. 45 and 46. It is made of four sheets, with right-hand rebates, each rebate being 5 in. long, the remaining edges being left unsoldered (see Fig. 44). Each quarter section is divided into four parts, with shears, to a distance of 8 in., indicated by a gauge line. The inner arc of this portion has a radius of 5 ft. 2⅞ in., and the gauge line for soldering is that of the horn end, 5 ft. 3¼ in. When rolled, soldered, and mounted on the horn, the sixteen loose portions are bent outwards to form a trumpet mouth (Figs. 45 and 46). Sixteen pieces of tin cut from scrap, 8½ in. long by 3 in. at their larger ends and of the shape shown at Fig. 47, are required. A ¼-in. gauge line run each side of each bent portion A (Figs. 44 and 46) will insure the symmetry of the flare if the pieces (Fig. 47) are truly cut to one gauge and soldered accurately to the lines A A.

Draw a 32-in. circle, in chalk or pencil, on a flat surface, place the trumpet on it, bell downwards, and trim up the rim. Then gauge a ¼-in. line round it, and turn outwards with the pliers to receive a ring of ⅛-in. brass wire B (Fig. 45). Solder this, and round up neatly by light hammering, if necessary, going over the work again with a hot bit and plenty of fluid.

Fig. 47.—Pattern of Pieces to be Soldered to Gauge Lines.

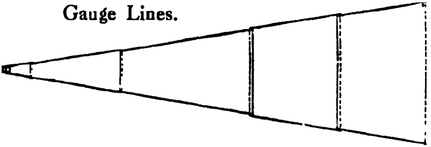

Fig. 45.—Section through 70-in. Horn.

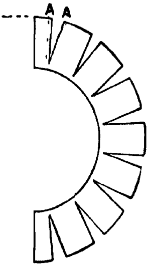

Fig. 46.—Half Plan of Flare, Rolled and Shaped.

Before cleaning up and enamelling, find the correct point of suspension, and solder on a strong brass wire eye.

Making Octagonal Horn.—The octagonal horn shown in elevation by Fig. 48, can be made of light sheet brass, say No. 26 B.W.G., or 1 × 28-in. by 20-in. tinplate. To obtain a pattern for one of the sides, eight of which when bent to shape and soldered together constitute the horn, draw first an elevation and one-eighth of the plan, as shown in Figs. 48 and 49. The elevational curve A D (Fig. 48) is now divided into equal parts, as at 1, 2, 3, 4, etc. From each of these points draw perpendiculars to cut the part plan (Fig. 49) in the points 1, 2, 3, 4, etc., on the central line A D. To draw the pattern Fig. 50, set off on the line A D the distances A 1, 1 2, 2 3, etc., being equal to those marked coincidently in Fig. 48. Through these points draw lines at right angles with the central line, and make A *a*, 1 *b*, 2 *c*, 3 *d*, etc., equal to A *a*, 1 *b*, 2 *c*, 3 *d*, etc. (Fig. 49). Then unite the points thus obtained to complete the pattern.

The top of the pattern may be either concave, as at *a a′ a* (Fig. 50), or convex as at *a* A′ *a*, according to taste; either gives a much better appearance than if left straight as at *a* A *a*. Mark and cut seven other pieces according to pattern, and if a pair of rollers are available, pass them through together, curling them each time in opposite directions to obtain an evenly-bent surface, and finally making them assume a shape approximating to A D (Fig. 48). The same result may be to some extent obtained by bending them similarly across the knee in pairs, afterwards shaping them with a mallet over a round stake or mandrel. These are now soldered together in pairs, adjusted to the proper angle. A good method of doing this is to cut eight small angle plates, and tack them in the wide mouth of the horn as follows. First fix an angle plate in each of the pairs, and solder them together inside, while the angle plate holds the pieces to the required angle. Two pairs are now held together with an angle plate, while they are soldered together inside to form one-half of the horn; the other half is made similarly. Finally the two halves are held together with angle plates and tacked in position, after which they are soldered inside as far as practicable, and then finished from the outside. All the

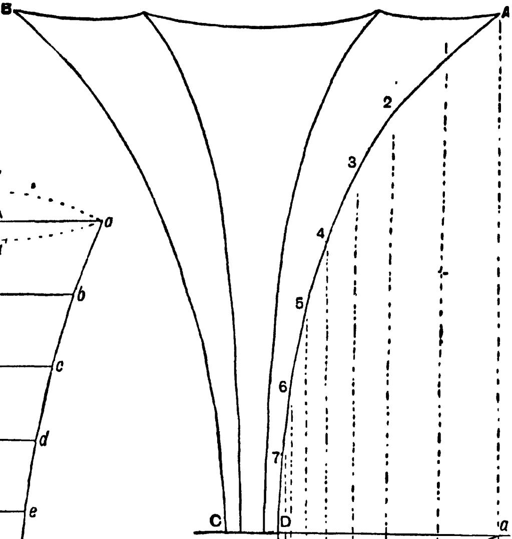

Fig. 48.—Elevation of Octagonal Horn.

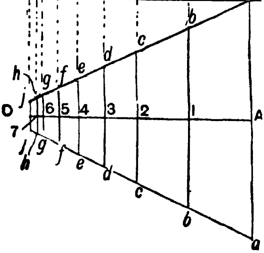

Fig. 49.—Part Plan of Octagonal Horn.

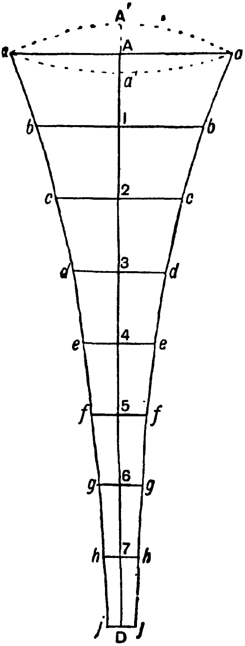

Fig. 50.—Side Pattern of Octagonal Horn.

angle plates are now released, and the surplus solder is melted with a hot iron and wiped off or floated into the seam. If the convex top of the pattern has been decided on, it should now be slightly bent further outwards with a mallet over a round stake. Of course, the extreme tops of all the pieces, whether convex or concave, are edged and flattened down before they are built together, so that the mouth edge of the horn will be smooth instead of presenting a burred edge.

The socket part of the old horn (the part by means of which it is secured to the machine) is now detached, and soldered in position on the new horn, which can then be suitably enamelled. Turquoise-blue is suggested as a suitable colour for the outside, and a better appearance is obtained if the inside seams near the mouth are relieved gradually with another colour.

Making Cardboard Horn.—A millboard or cardboard horn must be brought to shape by gradual bending. If the sheets are evenly damped until limp (by steaming, not soaking), they will be more easily shaped, and much depends on the correct cutting out of the plan. Fig. 51 makes a cone of about 18-degrees angle, 2 ft. long, 2 in. in diameter at the stem and 9 in. at the mouth; the dotted line indicates the seam. Lap seams are rather unsightly in thick board unless both edges are pared to a feather-edge; a 1-in. lap, well made, glued and dried under pressure, is quite strong and scarcely visible (see A). A butt-ended seam, secured by a glued strip of cardboard on the outside, and wide tape within (see B), answers well.

A set of half a dozen or more stout wire rings varying in size from 2 in. to 8¾ in. will greatly facilitate the formation of the cone and retain it in shape until dry. These are slipped on to the horn at intervals of a few inches to hold it together; others may be pushed inside if bulging occurs. No. 8 or No. 10 gauge galvanised-iron wire is suitable; scarf the ends for ½ in. to 1 in., and solder, then bend in the hands to an approximately true circle, beating out any kinks on a wooden mandrel with a mallet. The glue should be freshly dissolved, not too thick, and applied quite hot. The drying off should be thorough. Use the best Bristol board about $\frac{1}{16}$ in. thick.

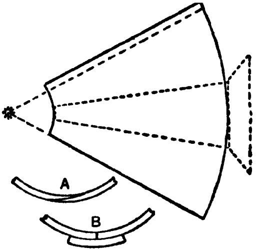

Fig. 51.—Cardboard Horn.

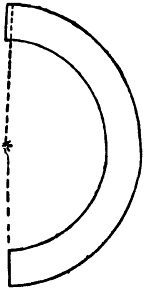

Fig. 52.—Flare for Cardboard Horn.

A curved flare is almost impossible to make in millboard. A plain one cut on the plan of Fig. 52 will do equally well; it will be improved if a stout wire ring is neatly glued and taped to the edge. Broad tape is first attached by half its width inside the flare and dried; when the wire is fitted, the loose edge of the tape is turned back over it and glued to the outside of the flare. It may be necessary to snip the tape in places with scissors to cause it to lie smoothly. A curved flare must be built up of many thicknesses of brown paper saturated in strong flour paste (or paste and glue mixed), and a mould must be employed. Made in this way, the flare must be allowed at least a week to dry. The mould may be the outside of a wash-bowl or basin of suitable curves; this should be warmed and coated with beeswax (or beeswax and resin) and dusted over with french chalk. In building up to the required thickness ($\frac{3}{32}$ in. to $\frac{1}{8}$ in.), every piece of paper must be thoroughly saturated in the hot paste, attached without creases, and thoroughly pressed down, rubbing out all superfluous adhesive from every layer. When quite dry the mould is warmed and the papier-maché flare removed, trimmed up with a sharp knife, glass-papered, and glued to the cone or body of the horn. A short tinplate or sheet-brass socket for attachment to the machine must be strongly glued to the trumpet-stem. Before painting, pasteboard must have two coats of strong, hot size and be allowed to dry. The paint will then go on smoothly and will not be absorbed. Of course, carriage varnish or shellac varnish may be used instead.

By another process the paper horn is to be completely saturated in diluted shellac varnish, dried and given a final coat to impart gloss. The first dressing may require three days to a week to harden, according to the thickness of the board and the state of the weather. A moderate and dry heat greatly expedites matters. Shellac varnish is made by dissolving flake shellac in good methylated spirit. Place the ingredients in a well-corked bottle and stand in a warm room for some days, shaking occasionally. The spirit had best be procured from a druggist. The stock varnish may be about as thick as glycerine, and it can be diluted with spirit to the desired consistency for use. The varnish dries rapidly, is waterproof, and carries a high gloss; but it is rather brittle if subjected to rough usage.

Making Paper Horn.—The following directions will show how to construct cheaply a 4-ft. 8-in. horn of paper. Procure six or seven large sheets of stout cartridge paper, double elephant size, which measures 27 in. by 40 in., and a bowl of good paste. Damp all the sheets evenly with a wet sponge, lay them in a pile on a bench or table, and paste the top sheet evenly and thoroughly. Next roll or twist the sheet of pasted paper in the form of a cone, the angle at the apex of which will determine the ultimate diameter of the mouth of the horn. The dimensions given in Fig. 53 have been found most suitable for the material in hand and for excellent results. The method of rolling is shown by Fig. 54, the centre of one of the long edges of the paper forming the apex of the cone. The inside should be pressed with a pad of cloth to remove any creases. The next sheet should now be pasted and the cone laid on it in the position indicated in Fig. 55. The corner A is drawn tightly over, and the whole rolled carefully to secure perfect contact. The inside should be again smoothed down. Proceed in this way sheet by sheet, each one that is added being allowed to extend beyond the last one 8 in. or 9 in., so that when five or six sheets have been pasted together the cone measures about 5 ft. long. If it falls much short of this another sheet should be added. To give strength to the mouth a last sheet can be attached without extending the length.

The drying will take several days in a warm room, when it will be quite stiff and hard, and ready to receive the bell-mouth, which is prepared as follows.

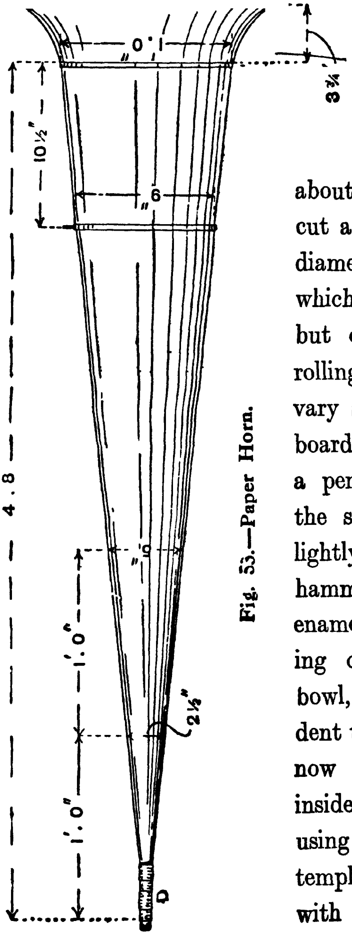

Fig. 53.—Paper Horn.

Procure an ordinary domestic enamelled iron bowl about 1 ft. 5 in. in diameter at B C (Fig. 56), which can be purchased for about 1s. Now mark out and cut a circle of cardboard the diameter of the paper cone, which should be 11¾ in. full, but owing to variations in rolling on the paper this will vary slightly. Lay the cardboard in the bowl and, with a pencil, mark round it on the side of the bowl. Tap lightly around this line with a hammer so as to chip the enamel. Repeat the hammering on the outside of the bowl, being careful not to dent the metal. A line should now be scratched on the inside of the bowl, again using the cardboard as a template, and then cut round with a small chisel or a hack-saw; the metal is easily cut, as it is very soft. The bottom part of the bowl is now discarded, and the rough edge of the upper part, which forms the bell mouth, smoothed with a half-round file. Mark a line $\frac{3}{8}$ in. from this edge, and with a pair of square-nosed pliers bend this $\frac{3}{8}$-in. piece slightly outwards, working round till a rim is formed (see Fig. 57), to fit the wide end of the horn. When it fits on square, run a pencil line round the outside of the horn, inside the bell-mouth, which should be removed and the horn trimmed neatly to the line with a strong pair of sharp scissors.

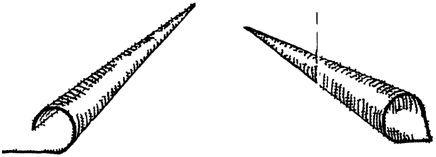

Fig. 54. Fig. 55.

Figs. 54 and 55.—Method of Rolling Paper Horn.

The bell-mouth can now be permanently fixed in position on the horn with glue or Seccotine, the latter for preference. Seccotine is also suitable for fixing the flexible connector D (Fig. 53), a portion of one or two layers of paper being removed with a sharp table knife, using a sawing action to avoid disturbing the inside layers of paper. The outside diameter of the horn at the point where it is cut should be a little less than the inside diameter of the connector. This latter should be purchased at a local phonograph stores. It will cost about **1s.**, and being plated it gives a good finish to the horn.

The balancing point of the horn must now be found by suspending with a piece of cord, and a line marked round it 2 in. nearer the bell-mouth than the point of balance.

To make a band (Fig. 58) for suspending from the ceiling by means of a chain or cord, cut a piece of $\frac{1}{16}$-in. by $\frac{3}{8}$-in. strip brass ½ in. longer than the circumferenec of the horn where marked to allow ½-in. lap. Before bending it to circular form, chamfer it so that the section is wedge-shaped (see Fig. 59). Then bend it to a circle with the chamfer inside, join up as shown, and solder. Drill a small hole in the band opposite the joint to receive the ring for the chain or cord; a picture ring with the screwed part cut off is suitable for the purpose. This should be

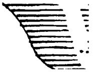

Fig. 56.—Bowl from which to make Flare.

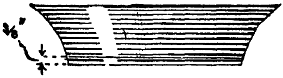

Fig. 57.—The Flare made from Bowl.

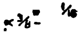

Fig. 59.—Section through Band.

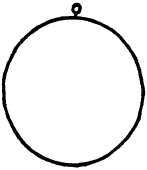

Fig. 58.—Band for Paper Horn.

neatly riveted into the band before slipping it over the horn, pushing it home tightly, with the thin edge of the band towards the mouth. The horn is now complete, and should have a couple of coats of japan black inside and out. Sizing is not necessary, the paste having filled the pores of the paper so that the japan will sink but slightly. The appearance of the exterior will be improved if, before the japan is applied, the edges of the paper are chamfered off with a piece of fine glasspaper. The brass band should be left bright. An ordinary stand can be used instead of suspending from the ceiling.

CHAPTER X

Constructing a High-grade Gramophone

THE motor for this machine is described in the next chapter, and its construction will constitute the most difficult part of the work. In Figs. 60 and 61 the letters have the same references as those on the illustrations in the next chapter. The position of the motor in its case is shown in elevation by Fig. 60, and in plan by Fig. 61. In the former, one side of the case is removed to indicate the manner in which the machine is wound and regulated for speed through apertures bored in the body of the case. Another hole is provided in the centre of the top for the turn-table socket and stem.

In Fig. 60 the motor appears in part detail only, so that the location of the brake bracket may be clearly shown. Reference to Fig. 61, in which the table socket and cover of the case are omitted, will render further explanation superfluous. The arrows indicate the direction of rotation of the spring stem, turn-table, and governor; the turn-table runs clockwise.

The case may be of any sound wood, but oak, walnut, or mahogany is recommended. The simplest framing is indicated in the illustrations; plain butt-ended joints, cleanly shot, glued, and nailed will suffice, the baseboard being attached with 1½-in. screws. Of course, a dovetailed, halved, or mitred-and-keyed body is preferable, the base and cover being framed of four or five parts, mitred, tongued, and grooved together. The illustrations show them as plain 9-in. squares only. Decoration may be added in the form of moulding on the edges of the base and cover,

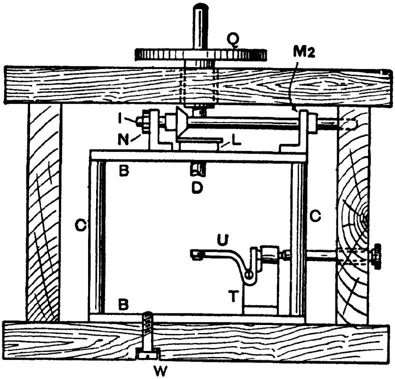

Fig. 60.—Elevation of Gramophone Motor in Case.

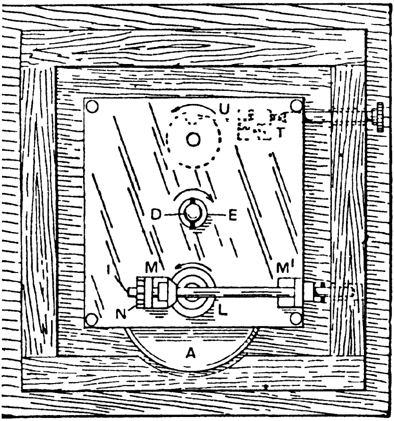

Fig. 61.—Plan of Gramophone Motor in Case.

and smaller, similar moulding may be mitred and attached to the body of the case, so as to give the effect of panelling.

After careful stopping and glasspapering, the case will look best french-polished; but a fair finish results from two coats of good varnish. The first is allowed to dry thoroughly, and then it is rubbed down with fine pumice powder and water before the final coat is applied. If an inferior wood is used, the work is best painted three coats (each when dry being well flatted with pumice), and finished with a coat of pale varnish. If a dull gloss is preferred, the finished surface of polish or varnish may be reduced with pumice, and subsequently cleaned with beeswax and turpentine, or similar furniture polish, when necessary.

Whatever wood is chosen or system of framing is adopted, it is important that the case shall be substantial. The illustrations show it framed in full ¾-in. stuff; and if oak or walnut is selected, a solid and weighty box will result. Much of the efficiency of a good motor is lost if it is mounted in a flimsy cabinet. The talking machine depends for its action on the energy of vibrations set up by the rapidly revolving record received and concentrated by the reproducer, and thence dispersed as sound waves by the horn. This energy is, of course, inversely transmitted to the body of the instrument on the recognised principle of recoil, motion, and counter motion. Therefore the more completely these reactions are absorbed, the more effectually will the initial energy be impelled in one direction, in this case through the horn. Thus the inertia of the heavy motor and case not only adds power to the sound-box, but also serves to absorb superfluous over-tones and to subdue the murmur of the high-speed gears. For the same reason a gramophone or phonograph should always be set on a substantial support when in use. A stout rubber button screwed to each corner of the baseboard, for the machine to rest on, has a good effect, insulating it from external tremors.

As previously mentioned, the motor is secured to the baseboard with three or four cheese- or mushroom-head Whitworth screws in convenient places. One of these is indicated at W in Fig. 60. The baseboard is countersunk to accommodate the screw head and a washer. For the rest, the illustrations are self-explanatory.

The sound-box, curved arm, and tone arm having already been dealt with in Chapters IV and VI, there remain for consideration the articulated elbow, the trumpet fitting, and the bracket which supports them.

The bracket A (Fig. 62) is usually of iron, but a wooden pattern (taking measurements from a suitable machine) can be made, and a casting procured from a local foundry. But the attachment may be built up of ¾-in. or 1-in. oak. That shown at A was designed by the writer, and it has been found quite rigid and in every way satisfactory.

The slanting and vertical limbs are of 2-in. by ¾-in. section, mortised together and glued, then cleaned up with the smoothing plane. The slanting limb is mortised (full width) into the rectangular cross-piece (6 in. by 3 in. by ¾ in.), and this is attached to the side of the cabinet with four stout 1¼-in. wood screws passing through washers;

or, more conveniently, with a pair of large winged or milled bolts and nuts (Fig. 63). By the use of these the bracket may be readily detached, rendering the machine more portable. The nut plates are attached to the inside of the case with two screws each. If a piece of wood of suitable grain can be obtained, the vertical and slanting limbs of the bracket may be cut from the solid plank if preferred.

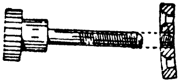

Fig. 63.—Milled Bolt and Nut for Attaching Bracket to Cabinet.

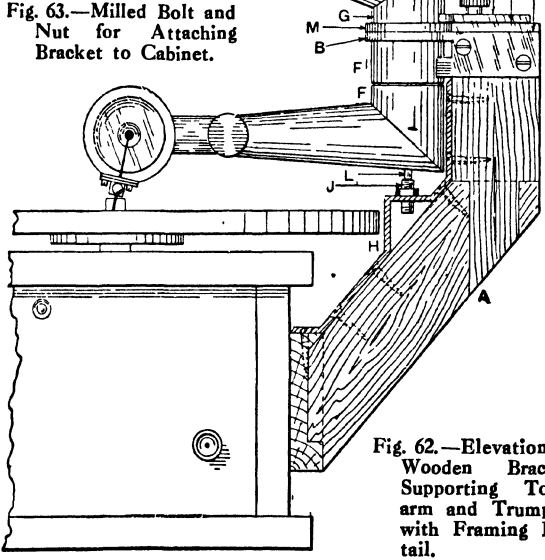

Fig. 62.—Elevation of Wooden Bracket Supporting Tone-arm and Trumpet, with Framing Detail.

The bracket crown stands 3¾ in. above the table and 7¾ in. from its centre, measuring to the inner side of the vertical portion. The mortices are indicated; that in the cross-piece is ⅜ in. deep (half the substance of the wood), and when gluing up, this joint may be further strengthened by a couple of 1½-in. screws (which are not shown) passing through the cross-piece into the slanting arm.

The fitting B (Fig. 62), shown in plan in Fig. 64, is next prepared. The material is ⅛-in. brass plate, the overall dimensions being 3⅛ in. by 4 in. First scribe the pattern on the metal, and then cut out with a sharp, cold chisel, finishing accurately to the lines by filing. The aperture to fit the upper limb of the articulated elbow F′ (Fig. 62) is 1½ in. in diameter. Mount the metal on the face-plate, and tool out a tight fit for the tube. If a lathe is not available, scribe the circle with dividers, bore a row of fine holes within it, chip out the centre, and finish to size with a fine-cut rat-tail or half-round file. Four countersunk holes for stout ¾-in. screws are drilled, and afterwards each side wing of the plate is neatly bent at right angles with the top (at the inner dotted lines), to fit the bracket crown, as in Fig. 62. The projecting tangs B² (Fig. 64) are bent inwards until they engage with the tube F¹ (Fig. 62), when the latter is in position, and soldered to it. The tangs effectively strut the tube; they are shown shaded in Fig. 62 to indicate the point at which

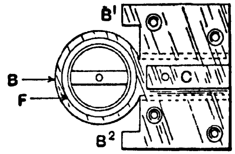

Fig. 64.—Plan of Bracket Crown-fitting.

Fig. 65.—Slotted Trumpet-clamp.

they are bent and turned inwards. The tube F′ (Fig. 62) is, of course, sweated into the aperture of the fitting B (Figs. 62 and 64), but this is not done until the inside of the tube is provided with its swivelling bridge, etc., to be described later.

The crown of the fitting should be finished flat and square, and then the strip of ⅛-in. brass C soldered to it. A tapped hole to take the milled stud, shown at E in Fig. 62, should be provided in the position indicated. The loose plate D (Fig. 62; see also Fig. 65) is slotted to allow a ¼-in. movement under the milled screw. This plate secures or releases the trumpet flange, as will be shown. The angles of the wooden bracket are reinforced by a strip of ⅛-in. brass plate H ¾ in. wide, which is attached by half a dozen ¾-in. countersunk screws. This binder is utilised to carry the pivot screw J of the elbow F. The screw may be ¼-in. Whitworth; it is bored ⅛ in. full to a depth of ⅛ in. to receive the pivot L, adjusted by a small tommy-hole in the head, and locked by a nut below.

It will be noticed that considerable care is taken to ensure the strength of the bracket; but it should be remembered that the attachment has to carry a large and heavy trumpet, and also to provide a rigid support for the tone arm and sound box. The framing suggested, as also that of the case, is simple, but improvements will easily suggest themselves.

As will be seen, the tone arm, etc., is an adaptation of the registered design of the Gramophone Company. In the writer's opinion it is the best form at present in use. The elbows in the original design have rounded contours.

but mitred joints may be substituted; these are of much simpler construction. They impart a neat appearance, and the tone of the instrument is not affected in the slightest degree.

To the instructions already given for the construction of the tapered arm, it is only necessary to add that for this machine the cone must be 5 in. long from the centre of the T-piece to the larger end, which must expand to 1½ in. in diameter. The large end is then mitred (45 degrees), to fit the similarly mitred lower limb of the articulated elbow F and F^1.

The articulated elbow F and F^1, and the trumpet socket G, are made from 1½-in. seamless brass tube; this may be had at 1s. 8d. per foot, and about 9 in. will be sufficient. The lower mitred portion of the tube F has a sleeve soldered within it, and below the sleeve is also soldered a bridge piece of ⅛-in. brass, ¼ in. wide, or less. This sleeve and bridge appear in section in Fig. 66 and in plan in Fig. 67. The sleeve projects half its width above the rim of F; this is trued up, and the projecting piece is reduced to make an easy fit within the upper limb F^1, leaving a shade of play (see Fig. 66). The limb F^1 is provided with a similar bridge to receive the end of the pivot L. (Fig. 62). This bridge piece is shown in plan and section by Fig. 68 and in position in Fig. 66. The upper tube F^1 has also an inner sleeve, projecting ⅛ in. from its top. The sleeves are made from ⅜-in. or ¼-in. cuttings from 1½-in. tube. The rings are split, and a sufficiency of metal removed to permit them, when again closed up, to make an easy driving fit within F and F^1; they are then sweated in and turned up. The centering of the ⅛-in. pivot holes in the two bridges must be accurate. It is best done in the lathe; but it may be effected by careful use of the scribing block or with the dividers.

The pivot is an ⅛-in. rod of silver steel. It is soldered into the bridge of the lower limb F, passes through the elbow (where it is also soldered), and it projects below, being supported by the set-screw J. The upper extremity swings in the central hole of the bridge spanning F^1 freely, but without side shake.

When F^1 is sweated into the aperture of B, and the struts B^2 (Fig. 64) are also soldered to it, and the whole fitting is securely screwed to the bracket crown, the elbow and tone arm are slipped into place, and the set-screw J is adjusted to bring the upper and lower limbs as close together as possible without actually bearing on each other. The reduced projecting portion of the sleeve sweated into F will enter without touching the bore of the upper tube F^1 at any point. A film of vaseline between the surfaces will complete the continuity of the jointed tubes, and render their junction sound-tight.

If carefully made, the arm and sound box will by this device swing practically without friction, yet with a maximum of steadiness and a complete freedom from rattle, which is essential to the best tonal results. If desired, a carefully dimensioned sleeve of brass tube may be slipped over the pivot stem to space the bridges in F and F^1 (Fig. 66), but this is not actually necessary. The great advantage of this almost frictionless arm will be particularly observed when playing "phonograph-cut" discs with the ball-stylus sound box. The Pathé and similar records carry a shallow U-shaped groove, and the stylus is apt to leave the track, and injure the disc by skidding if the tone arm has not a very free movement. The life of needle-operated discs, which have a sinuous V-groove of considerable depth, is prolonged also by the total absence of lateral drag on the needle.

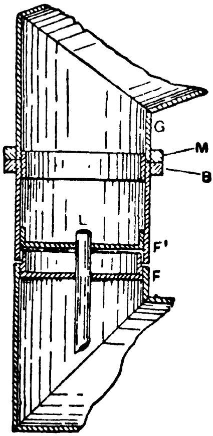

Fig. 66.—Section through Articulated Horn or Trumpet-Stem

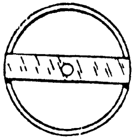

Fig. 67.—Sleeve and Bridge-piece.

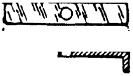

Fig. 68.—Bridge-piece.

The trumpet socket G (Fig. 66) is mitred at an obtuse angle of inclination to suit the flare of the horn selected. This and the right-angle mitre of F are best hard-soldered, as the strain on them is considerable. If, however, soft solder must be employed, small angle pieces should be riveted and sweated within them at the points of greatest stress. As will be seen, the lower limb of the socket G terminates in a ring of $\frac{1}{8}$-in. brass M, shrunk and sweated on, turned square at the edge, and faced to make a seating on the annular portion of B, the projecting sleeve of which enters the trumpet stem a snug, but not tight, fit. When the slotted plate D (Fig. 62) is run forward and clamped by the stud E, it retains the horn in position, yet permits it to be turned either way.

It is advisable to provide a stop to limit the movement of the horn, for if it is inadvertently swung round at right angles with the bracket, the latter may be strained, and if the trumpet is a heavy one it may even over-balance the whole machine, causing serious damage. A total swing of 30 degrees (15 degrees each side of the turn-table centre) is ample.

The fitting being completed, and the machine erected and found satisfactory, it should be taken down, and the whole of the brasswork freed from file marks, superfluous solder, and other blemishes with emery-cloth glued to wooden strips, and finished bright and smooth with fine emery and oil, followed by Bluebell or Globe polish. Every trace of grease should then be removed with hot water and soap, the work rinsed and dried, and finally buffed before it is warmed up and given a coat of lacquer, again gently heated, and set aside to cool.

Now carefully re-assemble the machine with clean hands, supporting the finished work on a soft cloth spread over the bench. Use new brass screws with polished and lacquered heads where necessary (not those previously employed during construction). Use a suitable screwdriver in good condition, and do not allow it to slip; leave the head slots all in one direction, and generally observe neatness in the final operations.

As to the trumpet, the conical form with moderately spreading flare is strongly recommended in preference to the "flower" type. An excellent horn to suit this machine may be made of stout tinplate, enamelled inside and outside, at the cost of about 1s. 6d. Its dimensions may be: Length overall, 2 ft. to 2 ft. 6 in.; diameter of mouth, 1 ft. to 1 ft. 3 in.; diameter of flare, 1 ft. 6 in. to 1 ft. 9 in. The form is not common on modern talking-machines, but it yields much superior results to those obtained from the flower type. The latter disperses the sound more widely, but the tone is unquestionably harsher and more blatant, lacking the fuller and more refined modulations of the conical horn.

In a small room the best results from it are obtained by standing the instrument as much as possible in one corner of the apartment, the horn being directed diagonally across it. The conical horn acts well in a long hall or schoolroom, if the machine is placed centrally at one end, and as near the wall as convenient, the trumpet pointing straight down the centre and inclined but slightly upwards. In a nearly square building some operators slowly swing the horn a few inches from side to side occasionally, to distribute the sound more generally. But this is unnecessary in a long room.

By way of conclusion, the following hints are offered: Lubricate the machine freely with a mixture of unscented vaseline and pure graphite. Remove the horn, and allow the machine to run down before laying it aside; do not let it over-run. Detach the sound box, and keep in a place of safety. Cover the machine against dust. Use only the best needles, and never use a needle twice. Dust every record thoroughly before and after use with a clothes or hat brush of long and pliant bristle (use it for no other purpose). An occasional sprinkle of french chalk, brushed well in and then completely removed from the grooves, makes for mellowness of tone in the reproduction, and materially lengthens the life of records.

When using the Pathé, or similar U-grooved discs, take care to reset or to renew the sapphire ball stylus directly it shows signs of scratch, or accumulates fragments from a previously dustless record. Give the stone a quarter turn to present a new and unworn surface; with care this may be done four times before the stone becomes useless.

Keep the records in envelopes and store, lying flat, in a cool but dry place. Do not pile up more than a dozen or so in one column.

Finally, search for, and remedy at once, any defect the machine may develop in use. If well made and carefully run, it will wear for many years and give results both in quality and volume equal to any similar talking-machine at present on the market.

"Hornless" Gramophone.—Fig. 69 explains the principle of constructing a "hornless" machine, as applied to portable machines. It amounts to little more than the provision of a deeper cabinet, and the inversion of the usual arrangement of the tone-arm, sockets, and stem. The motor is suspended from the cover by rubber-insulated bolts to deaden vibration. The internal portion of the horn may be of flattened rectangular form, its mouth expanding laterally to the full width of the case and tapering evenly to the bend. From this point it should be gradually brought to a circular section to meet the swivelling flange, the taper being constant throughout. But if the rectangular cross-section is carried right up to the flange (terminating as a square, not as an oblong), the cutting and soldering of the four parts would be very simple. A wide-rim flange (of circular section) could be soldered to the square orifice, and the tone would not be materially affected. The horn-mouth is commonly masked by a louvred shutter and two folding doors to regulate the sound.

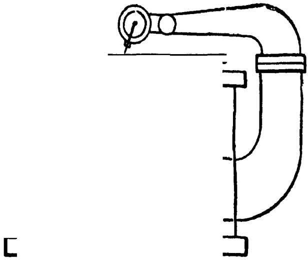

Fig. 69.—Hornless Gramophone.

It is agreed by those competent to judge that the self-contained or "hornless" machines do not favourably compare with those on which a well-proportioned trumpet is used, except in the matter of portability.

CHAPTER XI

The Construction of a Spring Motor

THIS chapter provides a complete guide to the general scheme of motor construction for the gramophone described in the preceding chapter. Figs. 70 and 71 are elevation and plan of the motor frame, etc.

The motor frame may be built up of two plates of $\frac{3}{16}$-in. well-hammered brass plate, say 6 in. square, and spaced 3½ in. to 4 in. apart by four stout iron columns turned to a shoulder at each end and provided with nuts. The wheelwork must be substantial, cut (not stamped), and consist of the following gears: Great wheel, say 2 in. in diameter, 65 to 70 cogs meshing with a pinion of 20 leaves, mounted on the same axle with the second wheel, which may be similar to the great wheel. This meshes with a pinion of 15 or 18 leaves attached to and revolving with the third wheel, 1¾ in. in diameter and of 50 teeth of finer pitch, which meshes with a pinion, or small wheel, on the turn-table stem of 25 to 30 leaves or cogs. On this axle also is a fourth large wheel of fine pitch, say 3 in. in diameter and carrying 180 to 200 cogs, which gear with the governor pinion of 18 to 25 leaves.

The spring drum may be 3¼ in. in diameter and about 2 in. deep. It is attached to, and turns with the great wheel on an axle $\frac{7}{16}$ in. or ⅜ in. in diameter. The turntable may be mounted on an axle of similar diameter, the base and top plates being bushed to afford it a longer and steadier bearing than the frame metal would allow (see E).

With a suitable spring, about 450 to 500 revolutions of the turntable should be available to one wind, and the machine could be wound, running, by means of a horizontal key stem revolving in bearings screwed to the top plate, and bevel geared with the spring stem in the proportion of 2 to 1. The ratchet wheel would be keyed to the winding stem, and the click (of the silent or springless type) fixed to the frame.

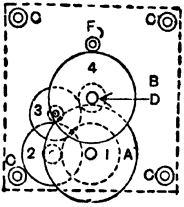

Fig. 70.

The motor could be mounted in a substantial oak box about 10 in. square and 7 in. high, with holes for the turn-table stem, winding stem, and regulator. The baseboard should be detachable, the motor being screwed to it. The tone-arm bracket could be cast in iron from a pattern copied from a suitable machine, or it could be built up in wood and reinforced with brass binding. The swivelling arrangements for the tapered arm and elbow will demand good workmanship. They could be adapted from the design of a standard machine, such as the genuine gramophone.

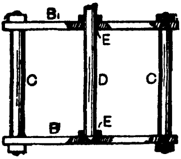

Fig. 71.

Figs. 70 and 71.—Plan and Elevation of Motor.

The rounded contours of the tone-arm and trumpet elbows may be dispensed with in favour of simple mitres; a right-angle joint for the tone-arm and one of obtuse angle for the trumpet connection. These details are fully dealt with in the preceding chapter.

Reference to Figs. 70 and 71 will make clear the description of the motor. In the plan, the wheels and pinions are numbered 1, 2, 3, and 4. Wheels 2 and 3 revolve on plain $\frac{3}{16}$-in. arbors screwed into the base-plate. No. 2 has its pinion uppermost, and No. 3 is above its pinion. Wheel 4 clears both these, its pinion being under it, in mesh with No. 3. The governor pinion is shown at F, and the spring drum at A, the great wheel (1) being, of course, below it. Below the plan is an elevation of one side of the frame with part of the turn-table spindle D in position to show the bushings E in section. In both illustrations the brass plates are lettered B, and the nutted columns C; one of these is in part section to show the shoulders and screwed ends. The manner in which the wheelwork is grouped may be varied to suit dissimilar wheel diameters to those given.

A machine constructed on the lines suggested above will operate a 12-in. record at one winding; it can be wound while running. If carefully built, it will give results in no way inferior to any similar machine, of whatever brand, costing from £5 to £15.

Fig. 72 shows the component parts of the motor, arranged diagrammatically in sectional elevation, with dimensions and the system of gearing. But it must not be taken to represent the motor as a whole, for, instead of being stretched out on a single line, the wheels are grouped as in the plan already given. It will also be seen that one only of several similar parts is shown; as, for instance, one spring and ball of the governor R and S, one frame column C, one screw and sleeve G, etc.

The wheels 1 and 2 should be $\frac{3}{16}$ in. thick, the other a full $\frac{1}{8}$ in. Wheel No. 1 is 2 in. in diameter, and has sixty-four cogs. Wheel No. 2 is of the same size and pitch; its pinion is $\frac{5}{8}$ in. in diameter, and has nineteen leaves. Wheel No. 3, 1$\frac{3}{4}$ in. in diameter, is of finer cut, say fifty-three cogs, its pinion having seventeen leaves. Wheel No. 3 meshes with a small wheel, or large pinion, $\frac{15}{16}$ in. in diameter and twenty-eight teeth, on the turn-table stem D. On the same axle is the large wheel No. 4, of fine cut, 3 in. in diameter and 180 cogs, which mesh with the governor pinion F, $\frac{5}{8}$ in. in diameter and twenty-one leaves.

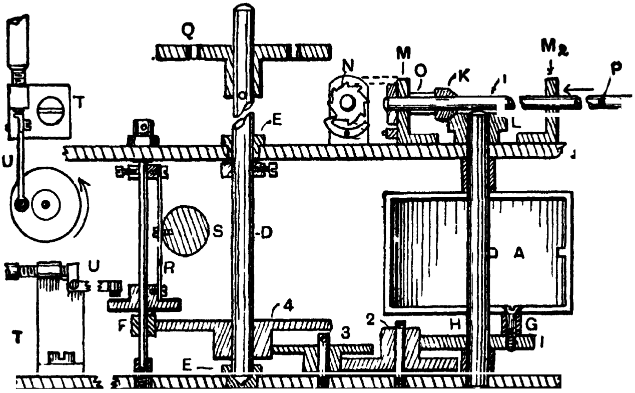

Fig. 72.—Sectional Elevation of Motor Parts.

The spring-drum A is 3$\frac{1}{4}$ in. in diameter and 2 in. deep. It may be made up from a cutting of seamless brass tube, $\frac{1}{16}$ in. to $\frac{1}{8}$ in. thick, with a brass disc of similar gauge at the top and bottom. The bottom disc is sweated in, and the top one forced in after the spring is in position. The axle H may be of silver-steel, $\frac{3}{8}$ in. in diameter; spurs are provided on the drum and axle for the purpose of engaging the spring. If necessary, a sleeve of suitable diameter may be pinned to this axle to accommodate a spring of wider centre than $\frac{3}{8}$ in.

The drum A and the great wheel 1 are coupled together by three or more countersunk screws, and spaced by sleeve pieces G. Both revolve together on the axle H, spacing sleeves being provided above the drum and below the wheel as shown. A horizontal wind is arranged by means of the axle I, of $\frac{3}{16}$-in. or $\frac{1}{4}$-in. silver-steel, which turns in bracket bearings of $\frac{3}{16}$-in. brass, attached by a $\frac{1}{4}$-in. cheese-headed screw to the top plate. These screws are not shown in the illustration.

The bevel-wheel K, of sixteen leaves, is secured by a set-screw to the axle I, and it meshes with the bevel-wheel L of thirty-two cogs, which is fastened to the spring-stem H by a set-screw. The click-wheel N may be shrunk and keyed on to the axle, or it may be pinned or brazed on. This part, with the silent type of click or ratch, is projected in plan from the section for greater clearness. Between the bevel-wheel K and the bearing M is the spacing-sleeve O; but, if preferred, the winding-stem I may be retained in position by a collar and set-screw on the outer side of M. This is not shown, but its position is indicated by the arrow in the right-hand top corner.

The winding stem is of sufficient length to project towards the wooden case a suitable distance to take the socket of the key, which enters by a hole in the case. A steel peg is driven through the hole P, to engage with a slot filed in the tubular socket of the detachable key used on these machines.

Wheels Nos. 2 and 3 revolve on $\frac{3}{16}$-in. arbors. Each of these is provided at the bottom with a washer of suitable thickness, and the wheels are secured above by a thin washer and split-pin passing through the holes shown.

The turn-table-stem D is of $\frac{3}{8}$-in. silver-steel running in the bushings E, which are of $\frac{5}{8}$-in. brass rod turned to a shoulder and sweated into the frame plates. The hole in the lower bushing is finished to a blunt cone, and the stem is similarly coned. This bearing maintains the full weight of the turn-table, disc, and sound-box; and greater durability (with easier running) would be insured by making the lower bush of hardened steel or case-hardened iron. In this case it will be better to screw it into the base-plate. The soldering of hardened metal is seldom satisfactory, even when the metal has been made perfectly clean and bright; and besides this, there is a probability that the temper will be "drawn." If a hardened centre is fitted, the lower end of the table-stem must be hardened also; but the temper of the rod must be well run down to leave the point only in a hard (and therefore brittle) condition. Medium straw-colour will be found a suitable temper for the cone end, if running in "dead-hard" carbonised iron. Of whatever material the lower bush is made, both should be bored a snug fit, and the stem ground in. If good results are looked for, the turn-table should be rigid and smooth-running. The stem is secured in place by the collar and set-screw shown.

The table is now invariably a turned casting in metal, but it may be an 11-in. or 12-in. disc of sound mahogany faced with velvet or billiard-cloth, and mounted on the brass socket Q with three or four screws. This socket may be a casting, or it may be made of ⅝-in. rod and a 3-in. disc of 3/16-in. brass plate sweated together, turned up, and bored to fit the stem. A lateral slot is afterwards filed below, to engage with a peg driven through the hole bored in the stem for the purpose. Wheel No. 4 may be fixed on D by one of several methods. It may be bored a "driving" fit, then warmed up, and slipped into place, when, on cooling, it will shrink on tightly. It may be keyed on, pinned on, sweated on, or fastened with a set-screw.

The governor pinion may be either shrunk or sweated to its axle. The latter is of ⅛-in. silver-steel turned to a blunt cone at each end. It runs in two iron or steel centres screwed ¼ in.; the lower of these is fixed, and the upper one adjustable and clamped by a lock-nut as shown (not in section). All wearing parts should be hardened. The upper brass boss of the governor, ½ in. in diameter and ¼ in. or ⅜ in. long, carries the upper ends of the springs It is a snug fit on the axle, to which it is secured by the set-screw shown on the left. The lower ends of the springs are screwed to a similar boss and friction-disc in one. This makes a sliding fit on the axle; the disc may be 1¼ in. in diameter.

The three springs are 2¼ in. long and ¼ in. wide. In the centres and at both ends of each are drilled, or neatly punched, 3/32-in. holes to take the cheese-headed screws shown. It is important that the springs are all of equal strength and temper, and that the holes are accurately spaced; otherwise vibration will be set up when the governor is running.

The weights may be spherical as shown, or ¾-in. cuttings from ¾-in. iron rod will do equally well. They must be exactly of the same weight, or the machine will vibrate.

The brake is mounted on a bracket, a convenient form of which is suggested at T. The lever U is shod with a piece of tough felt or leather where it bears on the disc. The regulating screw has a long stem, which projects a short distance through the outer case. The brake must engage the disc radially in a trailing direction as regards the motion, as indicated in Figs. 60 and 61.

Reference to the plan (Fig. 70) will show that in grouping the gears in the frame (which need not be more than 5 in. square) the turn-table stem D is placed centrally.

A diagram giving the correct positions for the pivot holes is impracticable in view of the necessary, if slight, variations of diameter and pitch of wheels supplied by various dealers. "Pitching depths" is a skilled operation, for which purpose the trade is provided with special equipment. Such work is best entrusted to a practical clock-jobber. However, the task may be accomplished if the greatest care is exercised.

The wheels being procured with centres bored to the sizes given, each must be temporarily plugged with brass or hardwood, and the plugs truly bored in the lathe $\frac{1}{64}$ in. to $\frac{1}{32}$ in. They should then be finished flush with both sides of each wheel and pinion. Next prepare a number of steel-wire pegs, fitting the small plug-holes, and point them keenly at one end. (If the holes are small enough, stout sewing needles will serve.) On these temporary axles the wheels may be plotted out on a piece of flat board on which a 5-in. square has been drawn to represent the frame-plates. Where necessary, cardboard washers may be interposed beneath the gears to bring them into position.

Wheel No. 4 having been firmly pinned centrally by its peg (which must be truly vertical), the next gear (No. 3) must be carefully meshed with its pinion, taking care that it is not set too deep or too shallow.

Wheels and pinions Nos. 2 and 1 are depthed in the same way. When the grouping is complete, including F, the wheels are removed and the pins neatly nipped off nearly close to the surface of the wood. By careful use of the dividers, the positions may now be transferred to the plates, and it will be found convenient to sweat these together for the time. From the central point scribe arcs with the dividers, testing one position with the next, and each severally with all the others. As a further check on the positions, a square of stout drawing-paper may be laid on the peg-ends and pressed down; the punctures will form a template, but do not rely on this alone. Too much care cannot be expended on the plotting out, as one minute error will throw out the work. Wheels pitched too deep run stiffly, wear rapidly, and set up vibration. When spaced too wide, the cogs are submitted to much strain, the gear works noisily, and is liable to break down at any moment. Well-cut wheelwork has a definite pitch-line or point of contact for the cogs; but the novice may obtain fair working results by depthing wheels and pinions to leave a shade of play between the cogs and leaves in every case. That is to say, if one wheel is rigidly held, the next may be very slightly moved in mesh. In brief, do not space so widely as to permit of rattle, nor so deep that the gear may jam.

The writer is not aware if the above method is in common use, but it is one by which he has successfully made up far more elaborate wheel trains than the one being described.

The plates being marked out, they may be drilled (see Fig. 70). Use a small drill in the first place, and see that all holes are taken through quite vertically. The holes for the arbors of wheels Nos. 2 and 3 are in the bottom plate only, and may be bored after the plates are taken apart; their size may be $\frac{3}{16}$-in. tapping. The other sizes are as follows: Spring-stem $\frac{3}{8}$ in., turn-table $\frac{1}{2}$ in. (for the shouldered lugs), governor pivots $\frac{1}{4}$-in. tapping, and corner holes for columns C $\frac{1}{4}$ in. This being done, unsolder the plates, drill the bottom plate for the arbors Nos. 2 and 3 (Fig. 72), and provide three or four tapped holes in suitable positions in the bottom plate, by which the wooden base may be afterwards attached. Tap the other holes required, remove the burrs, and polish up.

The wheels having been made up, the motor, so far finished, may be temporarily assembled by the four nutted columns. Next decide the positions of the brackets M and M$_2$, after carefully pitching the depths of K and L. Drill and tap the holes (not shown) by which these are attached to the top-plate. Find also a convenient position for the brake bracket on the base-plate, so that its felted lever may engage the friction disc, and its regulating stem may project through the outer case at a point to be decided. This detail, and others relating to exterior fittings, are dealt with in Chapter X.

The mainspring selected should be one which is compressed by about sixteen to twenty revolutions of the stem H, or thirty-two to forty turns of the cranked winding key. This power will spin the table between 425 to 500 times. At its normal speed (for needle-operated discs), seventy-five revolutions per minute, the governor will make about 630 revolutions per minute, sufficiently fast to maintain an effective braking resistance against U and ensuring a steady run. The machine may, of course, be wound while running.

CHAPTER XII

Inserting New Springs in Motors

THE usual procedure by which broken springs are replaced is as follows: First allow the machine to run down completely (if any power remains in the spring), and then detach the motor from the case or framework. As constructional details vary with different makes, it is impossible to particularise here; but an examination will quickly locate the points of attachment. The detached motor is now taken to pieces, separating the frames by removing the pillar nuts or forcing out the pegs. The motion work is taken out wheel by wheel, the relative positions being noted.

In modern machines the spring is usually contained in a drum, on one side of which will be found an aperture by which the loose cheek may be prised out, thus exposing the spring. Turn the axle backwards to detach the detent from the inner end of the spring, and remove the axle; a slot is usually provided through which the detent may be drawn. The fractured spring is now carefully removed, levering it out by degrees until its coils can be cramped or wired up. If the spring is withdrawn at one operation, it will violently uncoil, and may wound the hands or damage the work. Hold both the drum and the spring in a cloth.

New springs to fit any machine may be obtained from large factors. They are sold compressed and wired up ready to insert in the drum; while this is being done the wire is gradually levered off. When in position, the axle is inserted and turned until the detent engages the spring. The drum is now firmly held, and the axle and spring revolved until the drum detent finds the aperture at the outer end of the spring. Before replacing the drum end, completely fill it up with graphite and unscented vaseline, forcing the mixture among the spring coils. The machine can now be reassembled.

External springs (those not confined within a drum) are attached to the framework by their outer end; generally a loop is provided to fit one of the frame pillars. The insertion of these in the machine is even simpler than the process explained above, the confining wire being cut after the machine is put together. After the repair, wind and run the motion several times to distribute the lubricant within the drum and coils.

The following instructions apply particularly to inserting a new spring in a side-motor machine. First see that the machine is entirely run down; remove the four screws, and detach the side plate. Take note of the positions of the various gears. Remove the great wheel and barrel; spring out the side disc by inserting a small screwdriver in the aperture made for the purpose; detach the pinion from the spring (by turning it backwards), and carefully remove the broken spring. Before inserting the wired-up spring, see that it is right way about, so that the catches of the barrel and spindle will engage with the slots when the wire is released. Ease off the wire little by little, pushing the spring into the barrel meanwhile; do not release the wire until the coil is as far in as possible. Finally, detach the wire, when the spring will at once expand into the drum. Before replacing the side disc, fill up the spaces between the coils with lubricant as already directed. Ease the spindle into position with its catch, in the spring slot, put in the disc, reassemble the machine, and wind cautiously a turn or two until the outer spring-slot is caught by the drum catch. Wind up and run down the machine a few times, so as thoroughly to distribute the lubricant in the barrel.

CHAPTER XIII

Making Records at Home

THE home-production of sound records seldom proceeds beyond the experimental stage. And the reason for this is obvious: the operator soon realises that even the best-equipped reproducing machine is not adapted to the production of first-class records.

Few of the uninitiated appear to be aware that the professional recording machine is an apparatus quite distinct from the ordinary gramophone or phonograph. It is, in fact, a piece of heavy and very accurate plant, power-driven, permanently installed, and in some cases of massive construction. Apart from the machine, the recording-room is either a specially erected structure, or an existing apartment is much modified to meet the requirements.

These facts alone are sufficient explanation why home-made records so seldom compare with the commercially produced article. Nevertheless, home recording is full of interest, even when poor results are yielded; and if the experimentalist will proceed with care and patience, he may attain to such skill as will enable him to produce a really passable transcript of any recordable sound with some degree of certainty.

It has been explained that sound is recorded by engraving its vibrations on a wax surface by means of a cutting tool. The resultant sound-writing on disc or cylinder appears either as sinuosities in a groove of **V**-section, or dots and dashes in a groove of **U**-section, according to the shape of the tool and the manner of its application. It is with the latter system that the amateur is concerned, and therefore no more need be said of the **V**- or gramophone-cut than that such records cannot themselves be used to reproduce sound, it being necessary to transfer the engraving to a more durable surface by electro-metallurgic processes already briefly alluded to.

The energy of sound vibrations is comparatively minute, and it is necessary to prevent its wastage in every practicable way and to concentrate it in its original integrity at the cutter edge as free from extraneous influence as may be. Hence a solid machine is required, so that power may not be wasted among shaky joints, or absorbed by a flimsy structure. Obviously, too, a silent-running motor is desirable, because any noise or vibration it may make will be transmitted to the record, and will afterwards be heard as a running accompaniment to the sounds it is desired to engrave.

A marked peculiarity of records made on ordinary machines is this steady under-current of extraneous sound. It is variously described as subdued rumbling, rushing, snoring, or crepitating. The two last-mentioned defects are generally attributable to a defective cutter and inferior blanks respectively. And home-made records, as a rule, lack robur; they may be sufficiently loud, but there is a certain want of musical depth observable. Among contributory causes of this is a lack of rigidity in the machine.

When the flexible drum-head is set vibrating by sounds entering the horn, it should be as far as possible the only substance in a state of tremor; every other part of the apparatus should be so substantial as to remain silent under stress of the fluttering air waves, otherwise power is lost. A light and flimsy apparatus cannot engrave fully the vibrations of original sound.

The above generalities applied to an individual case will serve to explain the cause of many of the failures experienced by the novice. These instructions apply particularly to recording on the cylinder; disc recording is, on the whole, less satisfactory and much more expensive. The processes are in many ways identical.

The Recording Machine and Horn.—A solid and smoothly-running machine is necessary. It must be overhauled, thoroughly lubricated with vaseline and graphite, and silenced as much as possible by careful adjustment. Whatever situation it occupies, it must stand on a strong support. A slab of stone, marble, or slate makes an excellent basis for the machine, particularly if this is set on several folds of felting or cloth. The whole thing is then insulated from ground tremors.

The recording horn differs from the horn used for reproducing; unlike the latter, it has no flare, and it should be as non-resonant as possible. Small cardboard cones are sold for the purpose, but their effective use is limited to a narrow range of experiment only. There is no size or shape of horn suitable for all purposes; several must be kept on hand for special subjects. Fortunately, they are simply and cheaply made.

Millboard, sized and varnished (or enamelled), is generally serviceable; but cones of sheet-zinc or tinplate, seamed and soldered, are more durable. To arrest the resonance of the metal, the outer surface may be covered with several layers of brown paper glued on smoothly; or, better still, coarse string may be wound evenly and closely from end to end of the horn, then dressed with thin, hot glue, dried thoroughly, and varnished over all. A smooth coating of enamel inside the horn will still further improve it.

One essential should be remembered: it is imperative that the interior of the cone shall be smooth throughout and free from any obstruction. Even slight roughness or irregularity will account for loss of power or even confusion of the delicate sound waves as they pass to the diaphragm.

In all circumstances it is desirable to suspend the recording horn (however small), and to connect it to the machine by a short length of pliant and clear-bore rubber tube of ample calibre. The common practice of attaching the trumpet rigidly to the stem of the machine is one that courts failure, because not only do the sounds entering the cone reach the diaphragm, but also the tremors of the cone itself are mechanically imparted to the machine, causing interference and confusion.

Recording Diaphragms and Styli.—Broadly stated, there are but two types of recorder in use by amateurs, the Edison and the Graphophone (or floating) patterns respectively. In careful use there is little to choose between the results of either. The Edison (Fig. 73) is only adapted to machines of that brand, and cannot be employed on any other. The floating pattern (Fig. 74) can be used on any machine having a sliding carriage and feed screw. Because of its simpler construction, alterations and fine adjustments can be more readily effected in the case of Fig. 74. The Edison may be considered the more scientifically designed, and when in good order it works well; but if anything goes wrong it is not so easy to repair as the other. Edison recorder diaphragms are commonly of mica, and glass is in general use for the floating pattern.

The working principle of the recorder (Fig. 73) is as follows: A is the body or cell secured within the arm socket of the machine, and connected to the horn by a rubber tube. B is a disc hinged to the cell and carrying the diaphragm C, which is mounted on a rubber gasket. D is the cutting stylus in its metal holder. E is a tubular weight sliding in the stem of A; its lower end is rounded to lie in the countersink at the back of B. Its function is to convey the sound directly on the centre of the diaphragm, and at the same time to add weight to the hinged disc without impeding its free movement. (Blanks seldom revolve quite truly, and this vertical play is, therefore, necessary.)

The action of the other recorder (Fig. 74) is simple. The cell closely resembles that of a reproducer, except that its stem is not provided with lateral play. The stem fits the socket of the machine, which, of course, is hinged to permit of vertical movement.

The common form of stylus holder is shown on an enlarged scale at A (Fig. 75). It is made of thin sheet metal. An adjustable holder B is of stout, annealed wire. By bending the tail end, the angle of the cutter's setting may be varied, and the advantage of this will be understood later on. Styli are minute cylinders of hard crystal (sapphire is the best and most expensive stone). These are ground and provided with a perfectly smooth cutting edge, commonly of 90° angle. Some are cup-ended to afford a keener entrance and more regular shaving. The best quality styli are cheapest in the end; but for experimental work on inferior or gritty blanks, hardened steel cutters may be used.

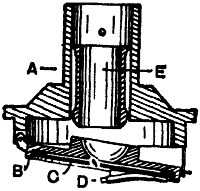

Fig. 73.—Edison's Recorder.

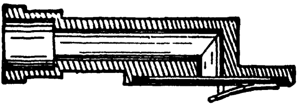

Fig. 74.—Graphophone or Floating Recorder.

Stout sewing needles broken into lengths and carefully ground flat-ended on a dead-smooth oil-stone will often yield as good a groove in the wax as the cheaper class of crystal stylus; if the steel is hardened it will be improved. Heat it to bright redness, and plunge immediately in cold water; afterwards repolish and carefully restore a fine edge on the stone. To grind accurately square-ended (giving a 90° cutting angle), force the needle fragment through a small piece of flat wood, and rub the latter on the stone, until on examination through a magnifier the cutter appears truly formed. Cutters are set in the holder with shellac or sealing-wax, and the holder is attached to the diaphragm with Seccotine or hard beeswax. At C (Fig. 75) the method suggested for grinding steel styli is shown, X representing the stylus, Y the wooden support, and Z the oilstone. If a final polish is desired after grinding, it may be imparted by tripoli, crocus powder, or rouge and oil spread on a glass slab, which is substituted for the oilstone Z.

Steel finished in this way is but little inferior to sapphire, except in the matter of wear; but this is of little consequence, for it will be seen that six or a dozen cutters may be ground and polished at one operation, and held in reserve for renewals. A good sapphire costs from 2s. to 5s.

The Blanks.—These should be the best procurable; those of the Seymour Manufacturing Company or Edison brands are recommended to those who have passed the experimental stage. Pathé blanks are also excellent. It is often asked whether worn-out gold-moulded records can be cleaned off and used for recording upon. Unfortunately this cannot be recommended; the material is altogether unsuitable for the purpose. Apart from other considerations, the hard, black "soap" rapidly blunts the cutter, even shattering its fine edge, so that it fails when next employed on blanks of the right composition.

The best recording blanks, as supplied in separate boxes, are "shaved" (that is, turned) perfectly from end to end. They carry a high gloss, and run very truly on the mandrel; in composition they are smooth and homogeneous, free from gritty particles, hard patches, or pin-holes. They are sufficiently soft, at ordinary temperatures, to cut cleanly, yet hard enough to bear a considerable amount of wear without deterioration if played with a reproducing point in really good condition. The best results are only to be had from a perfect blank newly shaved.

"Wiping" consists of erasing the recorded surface with a solvent such as benzoline, naphtha, petrol, or paraffin, applied with a clean linen rag free from fluff. The cylinder is first briskly rubbed from end to end, and when all trace of engraving has disappeared, it is smoothed off in the other direction, and a final polish is given with a silk handkerchief. But a blank once wiped has lost its best qualities; if erased several times the cylinder becomes lumpy and runs untruly.

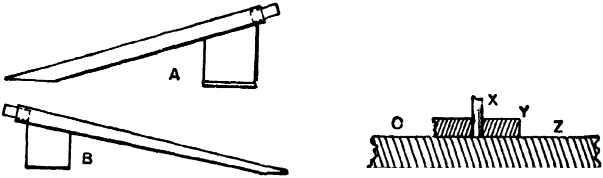

Fig. 75.—Stylus and Method of Grinding.

The best method of removing a record from a wax cylinder is by shaving. A shaver is an attachment to the carriage of the phonograph, which is fitted with an adjustable sapphire, or steel, cutter. This tool—acting on the principle of the lathe slide-rest—traverses the revolving cylinder from end to end, taking off a clean shaving. Some of the earlier Home and Standard Edison machines are thus equipped.

Shaving may be repeated many times until the cylinder walls become so thin as to be brittle. The better class of phonograph is provided with an attachment for shaving blanks; but failing this, most large dealers will undertake the operation for a small charge. Anyone possessing a small lathe may easily rig up a shaving device. The traverse should be slow, the speed high, and the tool buffed to a perfect edge of somewhat obtuse angle. The cut taken should be extremely light, only sufficient to remove the engraving at three or four traverses, or the surface will be splintered; a lubricant of glycerine and water frees the shaving.

The Recording Room.—An ordinary house offers little choice in this matter, and therefore only a general idea of requirements need be given. A long and narrow room is more suitable than a square one. Heavy carpets, furniture, and hangings absorb much sound; but a completely empty and uncarpeted room gives rise to echo and confusion of the record. A very lofty apartment is undesirable. Screens of various shapes and sizes are much used to deflect and regulate sound in professional studios.

The Easiest Records.—There is no doubt that one of the easiest sounds to record is that of whistling. Place the whistler opposite the horn, set the machine going, and let him whistle at the spinning blank. When the latter is dusted and tried over, the result will probably be a fair reproduction of the performance. Unfortunately, whistling records lose their charm on a few repetitions. The flute, the piccolo, and fife are not so easily recorded, as will be presently explained.

The next simple sound to reproduce is speech. A clear voice of tenor quality is easiest. The enunciation of every syllable must be distinct, and the volume of the tone should be kept up throughout. Shouting causes "blasting," but if the voice is dropped too low it will fail to record intelligibly. In brief, the recorder exaggerates every modulation.

Those who have been used to public speaking, or who have successfully studied elocution, will find little difficulty in making a good "talking" record.

Next in order of difficulty comes the reproduction of singing. Unaccompanied solo-singing, only, is referred to. To include an instrumental accompaniment with the vocal record is a further step. Duets, chorus-singing, and the recording of instrumental music are yet more advanced, and should only be attempted after experience in simpler work has been gained.

It is assumed that the general scheme of procedure already given in this chapter has been studied, blanks, spare diaphragms, and styli provided, and the machine (phonograph) put in the best condition to ensure smooth and silent running. Let the machine now be set steadily and level on a firm support, with a suspended horn attached by $\frac{3}{8}$-in. rubber to the carriage stem. The cutting of the stylus having already been tested and found to remove an almost unbroken, hair-like shaving, the speed is adjusted to 160 revolutions per minute, and the motor proved capable of maintaining that speed against the drag of the cutter.

Begin with the simplest subject, whistling. Engrave the blank in short lengths of 1 in. or less, and test each result with the reproducer as you go, modifying the next attempt as required. Employ a 12-in. by 4-in. millboard, or string-wound metal horn. Start the motor, and lower the cutter when it has reached normal speed. Approach the lips to about 6 in. distance from the horn, and direct the sound straight downwards into it. Go somewhat nearer while emitting low tones, or those formed by the indraw of air; but retire several inches when following shrill and rapid movements, piccolo imitations, shakes, etc., and also on powerful notes in the middle compass.

When trying over these separate lengths (the same trumpet will serve to reproduce, for the time being), take careful observation of the quality of the recorded sound in each case, and note the best results for future guidance. The gift of facile and melodious whistling is somewhat rare, but the writer has a few records of this kind that compare not unfavourably with others made by fife or piccolo.

Faults and Remedies.—Assuming the original sounds to have been clear and tuneful, analyse the several reproductions as follows: If generally weak, and in parts barely audible, the diaphragm is probably too stout for this special purpose, although it may be suitable for others. If the general effect is fair, but blasting occurs on high notes or rapid movements, the performer's methods were at fault, and must be modified on the lines suggested above. If the notes are not pure in tone, but betray harmonics, harshness, and a suggestion of buzzing here and there, a loose diaphragm or stylus may be suspected, and the defect must be found and made good with wax, shellac, or Seccotine, according to circumstances. Loud, but thin and blatant reproduction mostly indicates a flimsy diaphragm; but it may be caused by the stylus being set too far back and taking too deep a cut. If occasional falling-off to flatness is also evidenced by such a record, an over-deep cut is certainly indicated (by the slowing-up of the motor). The remedy, of course, is to bring the stylus a shade forward on the disc; if the holder has an annealed stem (B, Fig. 75), this may also be bent to present the edge of the tool at a less obtuse angle.

When it is desired to test a number of diaphragms in the same cell to suit a difficult quality of sound, time is saved by attaching the discs to the rubber gasket with hard beeswax (procured from a clock-jobber) instead of Seccotine or other cement. The glasses may be quickly fastened or detached by the application of gentle heat. No more than sufficient wax, a mere trace, evenly spread, should be used, or it will clog the glass and rubber, and impede their resiliency. The stylus holder may also be fastened with wax, just sufficient to give a firm hold on the glass. By warming up (with a piece of heated wire), the position of the cutter may be quickly altered, and this is often necessary to obtain a good result.

When a thoroughly satisfactory glass has been selected for a given range of subject, it is best permanently fixed in the cell with Seccotine or rubber solution. Several recorder cells, provided with discs adapted to various qualities of tone, should be kept on hand. No single diaphragm can render more than a narrow range of subject.

Records of Speech.—Before attempting to make a "talking" record, practise speaking into the horn with level, sustained, and distinct utterance. This is not the simple matter it may at first appear.

The average person speaks best when standing upright, in an easy attitude with the head slightly thrown back. A sitting posture is less desirable, and a stooping position tends to muffled tones. Therefore raise the machine about 5 ft. and let the mouth of the suspended horn be set to the level of the speaker's lips, in such manner as to permit the sound to travel into it almost horizontally. Let the machine run (without a blank or the recorder), and allow the carriage to traverse; then speak a sentence or two clearly into the horn at a distance of about 4 in. to 6 in. A little practice will familiarise the beginner with the sound of his own voice, raised considerably above its ordinary pitch, and employed under novel conditions. The slight sound of the running motor, conveyed outwards by the horn, will soon be disregarded, although at first it is not a little distracting.

Confidence having been gained, a record may be attempted. Wind the machine fully, put on a blank, and adjust the recorder in position ready to lower after the motor has fairly started. Now pause to make sure the sentences to be recorded are fully committed to memory; try them over, if necessary, in the tone that seems suitable. Avoid a too definite inflection on any individual passage, remembering that the recorder exaggerates over-contrasted volume. Then start the motor, lower the diaphragm, and speak without haste or nervousness for, say, half a minute, in sustained but natural tones. While pronouncing every word distinctly, avoid a too pedantic utterance or the record will accentuate this, rendering the subject-matter in tones of ludicrous affectation.

After half a minute's speech raise the recorder and stop the machine; dust the blank with a soft camel-hair mop, and remove all shavings. Then put on the reproducer and test the $\frac{3}{4}$-in. or $\frac{4}{5}$-in. length of engraving just produced.

Let it be assumed that the result is fairly satisfactory, serious defects having been already experienced, and dealt with on the whistled cylinders. If the record neither blasts nor falls off to inaudibility in places, and if the voice is readily recognisable as that of the speaker, it is proof that the diaphragm suits the voice, and that the latter was carefully modulated. A certain lack of power may be tolerated if the reproduction is clear and otherwise pleasing. Attempts to increase volume (by louder speech or a nearer approach to the horn) may result in blasting, harshness, or a generally unnatural rendering of familiar tones. To obtain more power, while retaining the better qualities of a subdued record, may necessitate the use of a different diaphragm or horn, or both.

Individual voices, even if superficially similar in key, often require widely dissimilar treatment. The length and taper of the recording horn greatly influences results. Taking a 12-in. by 4-in. cone as the standard for talking records, special qualities of tone and methods of oral delivery will be better rendered by other lengths and apertures.

A high-pitched voice, or one of distinctly nasal production, is best recorded through a narrow-angle horn, 25 in. to

36 in. long, which has the effect of subduing over-staccato inflections. A full and musical bass or baritone is sometimes found to record in a natural manner through a very small mouthpiece but little larger than that of an ordinary speaking-tube. Three useful sizes to begin with are cones of 4 in. by 2 in., 12 in. by 4 in., and 25 in. by 5 in. (the largest will be of service for vocal and instrumental work).

With these, systematic tests should be made, and careful notes taken of the several results for future guidance. The horn-length will be found to influence the action of a given diaphragm to a marked degree. A thin disc that will blast and chatter badly with one cone will work smoothly with another, and a thick glass giving a barely audible result under some conditions will yield a powerful and clear record in others.

Experience must be gained by actual practice and close observation. No hard and fast rules can be given to ensure success for a given subject.

Further Hints on Making Records at Home

Records of Vocal and Instrumental Music.—All that has yet been explained as to recording applies and leads up to the present section, which will deal briefly with the engraving of vocal and instrumental sounds.

Experiments in speech-recording on the instructions already given will doubtless have been varied by more or less successful attempts to reproduce song; experience will have been gained as to the management of the voice and the modifications of horn-length and diaphragm substance to reproduce a given effect.

Most vocalists have become habituated to an accompaniment of some sort; and it is advisable that the singer, while facing the horn, shall be supported by an accompaniment on his familiar instrument (say, the piano), even if no attempt is made to record the tones of the latter.

It has been explained that an ordinary room is ill-suited for recording; but something may be done to remedy its defects by means of a large three-fold screen of which a number of uses may be made. For records by a vocalist who prefers to stand while singing, a screen of less than 6 ft. high is not of much service; but a much smaller one may be turned to account for other purposes.

In addition to the screen a top-resonator is serviceable in special cases. This may be a light wooden framing, 3 ft. or 4 ft. sq., covered with millboard, lincrusta-walton, or stout brown paper. These accessories, in careful use, greatly assist the production of full-quality records without excessive contrast, the modulations of power being more evenly graduated. It should be the smooth blending of the piano and forte passages of musical sound that is studied, after the initial difficulties of recording are overcome. But, of course, these "sound-reflectors" may as easily be misused as light-reflectors often are by inexperienced photographers.

As a preliminary test, let the screen be folded as in Fig. 76, the singer taking his stand within it, at v, and facing the 26-in. suspended horn H, the phonograph being raised to a convenient height as already explained. In these new conditions, it will be found that a record of fair power may be engraved with considerably less strain on the voice than is possible without the screen. But the quality of the sound must be carefully observed. If indistinctness, confusion, or booming occurs in parts of the reproduction, the screen must be set open wider and the horn removed farther away. Of course, the usual precautions must be taken to retire a few inches on high notes and to approach nearer on the low ones. If the screen is sufficiently high the effect of the top screen may be tried. This is not applicable to all cases, but it is useful to concentrate a voice insufficiently powerful to record in the ordinary way, except by a too close approach to the trumpet-mouth (and a consequently unnatural production).

In general terms it may be stated that the screen, with or without the top resonator, permits the machine and horn to be placed farther away; an advantage tending to a more even and natural reproduction. The extremes of contrast (from "blasting" to inaudibility) are indeed very efficiently modified and toned down by judicious employment of the screens.

A piano or other accompaniment supporting the singer may be played in the same apartment, but it will be practically inaudible on the record unless special arrangements are made; these will be referred to later.

Some voices concentrated by the screen folded as in Fig. 76, yield a "boxed-in," smothered or booming sound on reproduction. The method is best suited to tenor, soprano, and treble qualities of tone. A baritone is often better rendered by the arrangement shown by Fig. 77, the wings of the screen being swung to various angles during the tests. In Fig. 78 a good experimental formation for a basso is indicated, the wings being adjusted as required; the greater the power the wider may the screen be stretched, until it becomes practically a backboard, only to project the sound.

There is an indefinite quality in certain voices that lends itself to satisfactory reproduction. This quality is not obvious to the ear, but it is observable that some very ordinary singers can make a passable record, and in some cases it is difficult to do justice to a really good voice. The peculiarity is to be noted among the greatest vocalists. Caruso's records disappoint many who have heard the great tenor, whereas the fine voice of Ben Davies records with singular sweetness and fidelity.

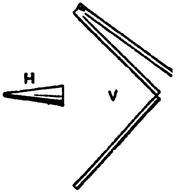

Fig. 76.

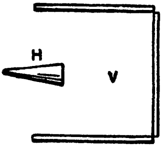

Fig. 77.

Figs. 76 to 78.—Use of Resonators for making Vocal Records.

Fig. 78.

A well-produced baritone voice will be found easiest to record, bass and tenor qualities less so; alto, soprano, and treble seldom repay the trouble of home-recording.

Among female voices, contralto will be found to reproduce tolerably. The instrument for accompanied singing, most commonly in use in this country, is the piano; but its tones are not easily recorded together with the voice. The horn must be focused on the back of the instrument at about the level of the keyboard, the singer being between the horn and the piano. A grand piano is less suitable than an upright "semi," or cottage.

In professional recording-rooms the piano is raised on a substantial platform about 3 ft. from the floor. This is generally impracticable in ordinary circumstances, and therefore the piano must be drawn well out into the room, and the singer be seated on a low stool behind it, near the treble end. The phonograph may rest on the floor (on a felt pad), and the suspended horn be directed as shown in the plan (Fig. 79), where P is the piano, H the horn, and V the singer. Here, again, use may be made of one or more screens; one placed as S is generally serviceable to concentrate the voice. The relative distances of machine, piano, and vocalist will depend on circumstances; several trials must be made to determine the best positions.

While making piano records neither pedal should be used, accentuation being imparted by touch alone, because the "soft" pedal will be found almost to mute the recorded sound; and the "hard" one causes confusion and discord. The performer should play with crisp execution and as powerfully as the character of the piece permits. This is one of the reasons why piano records (as solo or accom paniment) are seldom satisfactory.

Duets may be attempted (with accompaniment) by seating the singers as close together as possible (at vv, Fig. 80). If one of the voices is considerably stronger than the other, the more powerful voice may be directed over the shoulder of the singer nearer the horn. A trumpet having a wider flare than usual may assist the blending of the voices.

An alternative method is indicated in Fig. 81. Here the angle of the horn is modified to permit the vocalists to occupy opposite sides of its mouth. If solo passages occur in the course of the selection, each singer in turn should lean forward and deliver his part as directly as possible into the horn mouth. On the resumption of the duet, both singers may draw back slightly, and blend their voices by singing across the horn. Screens s may be employed, and even a top-resonator, but this may inconvenience the singers (whose positions will already be sufficiently cramped).

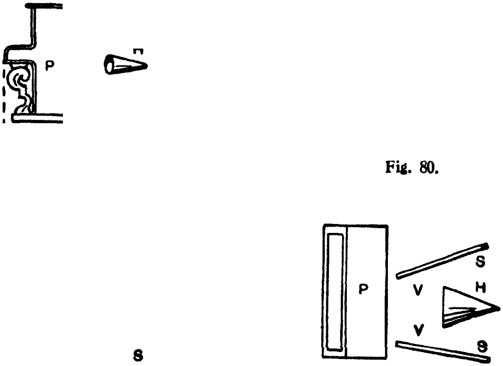

Fig. 80.

Fig. 79.

Fig. 81.

Figs. 79 to 81.—Recording Songs with Pianoforte Accompaniment.

The usual method of making piano records has been briefly referred to. An upright instrument must be drawn well out into the room, and the phonograph set on the floor behind it (resting on a felt pad). The 20-in. to 30-in. horn is then directed towards the treble end at about the level of the keyboard; several tests should be made to find the best distance to suit the diaphragm in use. Screens and a top resonator will be of service to concentrate the sound. In the case of a grand piano, the top screen is superfluous, as the cover of the instrument, when raised, will serve the same purpose. The involuntary use of the pedals may be prevented by strutting them with a piece of wood, or two bottle corks.

The violin, tenor-violin, 'cello, and double-bass are difficult to record by the amateur. In the case of each of these instruments, the performer's convenience should be first considered. Then the operator must place the phonograph as near as possible to the musician without impeding his movements, the horn being focused upon the *f*-holes of the instrument. A violinist usually stands while playing, therefore the machine must be set up 6 ft. or more from the ground, the suspended horn being drooped towards the belly of the violin. For the 'cello and other large instruments which are rested on the floor, the machine also is placed low (at a height of 2 ft. or 3 ft.), and the drooped horn focused from that position. It is important that the horn-mouth shall be brought as near as possible to the *f*-holes, leaving only sufficient space for the free movement of the bow. Screens suitably placed are useful to concentrate the sound. A 26-in. to 30-in.

wide-angle trumpet best collects the large tones of a 'cello or double-bass; but an 18-in. horn of ordinary angle picks up violin music more crisply. The guitar, mandoline, and banjo may be recorded similarly to the bowed-string instruments, the horn-mouth being approached close to the sound centre in every case.

Wind instruments, as a whole, are easier to record than the stringed group, probably because the reed vibrations emanate from a relatively small centre of high concentration, and are impelled to a great extent in a definite direction.

A chamber organ yields a far better record than a piano; the same procedure serves for either instruments but the backboard of the organ should be removed and a top-screen used just above the horn and the panel opening. A stouter diaphragm and a fairly large horn of wide flare may be employed for the preliminary tests of distance and direction.

Among brass instruments the cornet may be cited as an example. Use an 18-in. by 6-in. recording horn, and let the player stand at a distance of about 10 ft. away from it, and direct the bell of his instrument straight at the horn; on high notes or very powerful passages he should turn slightly aside. In a small apartment no screen is necessary; but in a large hall the player may need to approach nearer, and one or more screens may be set to prevent a too wide distribution, or echo of sound. Several combinations of diaphragm and horn should be tested on lengths of the trial-blank, and when the best arrangement is arrived at, a really good result may be confidently expected from the cornet, which records singularly well.

The wood-wind group records with facility, but trouble will probably be experienced in transferring the peculiarly soft tone of these instruments to the waxen cylinder, which is apt to introduce a metallic quality into the reproduction. A stout millboard horn (varnished) is desirable for recording; the tinplate ones, even when heavily muted with glued string or paper, are less suitable.

To take a clarinet record, set the phonograph on the floor and suspend the 18-in. by 6-in. horn slanting upwards to receive the tones of the instrument when played in the usual way. The angle of the horn must be arranged to suit the performer (whether seated or standing), so that the sound is focused in as direct a line as possible from reed to diaphragm. If the tone of the record is thin or metallic, try the effect of a carbon diaphragm and a 30-in. horn (of millboard or heavily muted metal), and approach the end of the clarinet more closely, to a point almost within the wide mouth of the horn.

The piccolo, flute, etc., are recorded by focusing the horn on the embouchure, or lip-orifice of the instrument. Quite a small horn will pick up the brilliant staccato notes of the piccolo, but a larger one does better with the flute; a fairly stout diaphragm is desirable for the former. A screen to the left of the performer is useful.

For instrumental duets, trios, etc., two or more recording horns are sometimes used, each being focused on its particular instrument or group of instruments. Two horns, with their stems connected to the machine by a Y-shaped metal union and rubber tubes, would be employed, for instance, for a piano-accompanied song with violin obligato.

The singer would occupy his usual recording position at the back of the piano and facing one horn, as previously explained. The other horn would be swung to a convenient angle to focus the violin, and in this way a fuller rendering of the vibrations of the several sound-sources is obtained.

The double **Y**-union (Fig. 82) should be of narrow angle, the brass tubes composing it being carefully fitted together to ensure a smooth and unimpeded passage for the two sets of converging sound-waves. The bores of triple or multi-unions also must be uniform and blended with the single stem at an even narrower angle, or the sound will be imperfectly blended on reaching the diaphragm.

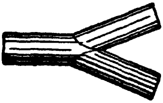

Fig. 82.—Double Y-union for Recording Horns.

Detailed instructions on recording a full band are scarcely within the scope of this chapter; but a brief summary of ordinary practice may be of interest.

A single large recording horn is employed of 5 ft. 6 in. by 18 in. to 20 in.; although it is of the non-resonant type, a flare or bell-mouth is often used. This is suspended at about 4 ft. from the floor. The bandsmen are grouped according to the power of their instruments, the back rows of musicians being raised several feet above the others to enable every performer to accurately focus the horn without interference; special positions are allotted to soloists. In general terms the various distances from the horn-mouth are arranged as follows: The piccolos and flutes nearest, at 2 ft. to 3 ft. Clarinets next, ranged up on each side and raised a foot or two from the floor. Beyond these the heavier of the brass instruments at 4 ft. to 8 ft.; cornets at 7 ft. to 10 ft., and the largest bass-brass at 10 ft. or more. Drums are found to confuse the record, while a number of other instruments are contributing to it; but alone, the drum records well, and is employed with good effect (solo) in brief pauses of a selection in which such emphasis is desirable; its distance may be at 8 ft. to 10 ft. from the horn. The big drum is never used in recording serious music.

CHAPTER XIV

Making Recorders for Phonographs

THE two recorders to be described in this chapter are each typical of their class.

Edison Recorder.—Fig. 83 shows the Edison type in section; the body A (of which Fig. 84 is the plan) is a German silver or brass casting. Allowance must be made in the pattern for shrinkage and machining. First chuck by the rim, in recessed hardwood, and bore out the trumpet tube B to $\frac{1}{2}$ in. in diameter; next turn the outside of the latter to $\frac{5}{8}$ in. and true up and shape the back. Reverse, and chucking by the finished tube, tool out the recess $1\frac{5}{16}$ in. in diameter and $\frac{1}{4}$ in. deep. Turn the rim $1\frac{1}{2}$ in. to fit the speaker-arm setting, leaving a $\frac{1}{16}$-in. flange as shown. Remove the chuck from the lathe with the work still in it, and in the rim file three flats $\frac{5}{32}$ *in. deep (see*

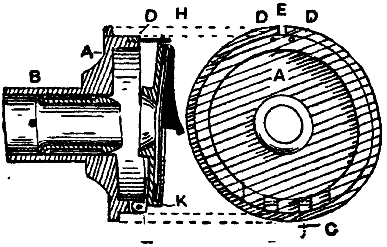

Fig. 83. Fig. 84.

Figs. 83 and 84.—Section and Plan of Edison-type Recorder.

Fig. 84), leaving the two portions C to form one side of the hinge. Also bore two $\frac{1}{32}$-in. holes at D to receive the brass wire staple, which is shown in position in Fig. 83. Remove from the chuck and file the slot E (Fig. 84) in the rim to accommodate the speaker-locating pin of the machine.

The diaphragm disc (Figs. 85 to 87) in the original is a stamping. It may be cast, but it is conveniently built up of $\frac{1}{16}$-in. brass plate, with a $\frac{3}{4}$-in. disc of $\frac{1}{8}$-in. brass at the back (see F, Fig. 87), and a $\frac{1}{8}$-in. ring of flattened wire in the front. These three portions are secured together with binding wire and soft-soldered, using plenty of zinc chloride as a flux. Chuck in hardwood with the ring outwards, and work out the recess to $1\frac{5}{16}$ in. in diameter, boring the central hole $\frac{5}{16}$ in. Reverse and re-chuck on hardwood, fitting the recess; turn the rim to $1\frac{3}{8}$ in. full, and the central boss to $\frac{9}{16}$ in. Then face up and countersink the hole to $\frac{1}{2}$-in. bare in diameter. Observe that the countersink has a rounded contour, which extends to the face of the disc, forming almost a knife-edge.

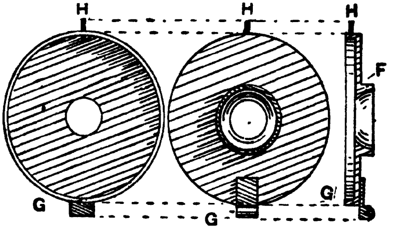

Fig. 85. Fig. 86. Fig. 87.

Figs. 85 to 87.—Front View, Back View and Section of Diaphragm Disc.

File up a small piece of brass G, to form the moving limb of the hinge (see Fig. 83). Fit it accurately between the portions of the rim C left for the purpose, without side shake. Place the diaphragm disc on the body, as in Fig. 83, and note the location on the disc of the moving part of the hinge. Then solder it to the back of the disc. Assemble the disc and the body, and bore the hinge $\frac{1}{32}$ in. for its pin. On the opposite edge of the disc bore a $\frac{1}{32}$-in. hole at a point midway between the two holes previously bored in the body rim at D, to take the pin H.

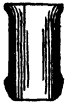

Fig. 88.—Tubular Weight.

The tubular weight, shown in section in Figs. 83 and 88, may be a casting, and can be built up of two sizes of tube, or it can be turned from solid rod. Its length is $\frac{3}{4}$ in., and it makes a sliding fit within the body tube. When the recorder is in position, the rounded end of this tube falls within the countersink of the disc, and accommodates itself to the movements of the latter, as it gives and takes to the running of the blank (which seldom revolves quite truly). The function of the tube is also to convey the sounds received by the horn directly on the centre of the diaphragm irrespective of its movements, and this it accomplishes both ingeniously and simply. A wire staple $\frac{3}{8}$ in. long is driven into the holes D, the hinge is pinned, and a short piece of brass wire is screwed or forced into the rim at H to prevent the diaphragm disc falling open.

All that now remains is to attach the diaphragm and stylus. The former is of mica, and is procurable for a few pence. It is mounted on a rubber gasket K the same way as a reproducer disc is fixed, using hard wax or strong gum. Excess of adhesive must not be allowed to impede the vibrations of the diaphragm, which must not touch the metal at any point.

The stylus and its holder are best bought complete (costing about 7s. 6d.), but if this is too expensive, a holder is readily made, and good sapphire cutters are to be had for 2s. and upwards. Figs. 89 to 91 show a popular type of stylus holder. For clearness, the illustrations are drawn about three times the correct size. The holder is bent to form in thin sheet metal, and the cutter J is secured with Seccotine or hard wax. A convenient form of holder is shown by Fig. 92. K is a small block of brass, to which is soldered a $\frac{5}{8}$-in. or $\frac{1}{2}$-in. length of $\frac{1}{16}$-in. soft brass wire L. This is tapered as shown, and the end is flattened. The other end is bored to take the cutter. The writer designed this holder to permit the angle of inclination to be altered as desired, which can be done by bending the tail either up or down, the holder being first removed from the diaphragm.

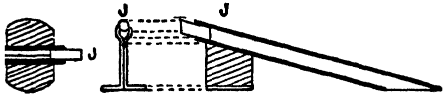

Fig. 89. Fig. 90. Fig. 91.

Figs. 89 to 91.—Stylus Holder.

Fig. 93 shows another holder which is readily fashioned from sheet metal. It has a portion of an ordinary sewing needle, about $\frac{1}{32}$ in. in diameter, soldered to it; the cutting edge as J (Fig. 91) is formed by grinding on a fine, hard oilstone. If care is taken with the bevel of this little tool, quite good work is possible with it. It can be made in a few minutes, and its cost is practically nil.

Graphophone, or Floating Recorder.—Figs. 94 and 95 are sectional views of a typical recorder of the floating type, fitting any cylinder machine of the graphophone pattern. It may be a solid casting, or it can be made in two parts, the disc and back tube extending only to M, the stem being afterwards fitted. The casting, cored or otherwise, must be centred at each end of the tube, and the latter bored in the lathe, the socket N being finished with a $\frac{7}{16}$-in. D-bit to fit the reproducer stem of the machine.

Fig. 92.

Fig. 93.

Figs. 92 and 93.—Alternative Forms of Stylus Holder.

It is then mounted, face outwards, in recessed hardwood (a part of the chuck being slotted to take the back tube), and the face recessed $\frac{1}{16}$ in. by 1⅜ in. in diameter and the central hole bored ¼ in. full. Reverse and re-chuck on a mandrel fitting the central hole, or by the recess on hardwood, and trim up the rim with a light cut taken with a long tool to avoid the swing of the stem. The back is finished by filing or planing, and, lastly, the stem is turned up on centres, or on a short mandrel fitting the socket N. The diaphragm and stylus are mounted in the usual way.

Fig. 96 shows a convenient form of recorder easily constructed of sheet metal and tube. The disc is turned from ⅛-in. brass or zinc, a 1¾-in. or 2-in. square of which is flattened, annealed, and attached to a wooden faceplate by means of four small screws, one in each corner. Face up and tool out the recess to 1⅜ in. by $\frac{1}{16}$ in. deep, bore the central hole ¼ in. to $\frac{5}{16}$ in., and with a narrow parting tool, cut out the disc 1½ in. in diameter. Reverse and mount truly in recessed hardwood, face up, and recess the central hole $\frac{1}{32}$ in. deep to ½ in. in diameter. Take a piece of ½-in. brass tube, and mitre one end to an angle of 45°. Mount the tube in the lathe and part off a full $\frac{1}{32}$ in. below the heel of the mitre N (Fig. 96). Mitre another length of the same tube, and cut off 1⅝ in. from the heel of the mitre; slip a ¼-in. length of larger tube over the unmitred end, and solder (see O). This is to provide sufficient metal for the set screw, which is not shown in the last-mentioned figures, but which is lettered P in Figs. 94 and 95. Assemble by forcing the short mitred tube N into the recess, and attaching the longer one to the back of the body with a few turns of binding wire, making a close joint of the mitres. Dress with zinc chloride and heat up; again apply the fluid, and place a few scraps of solder along the joints. Heat up until the solder runs cleanly into all seams, wash thoroughly and repolish. Then heat gently and lacquer, giving two thin coats, allowing an interval for

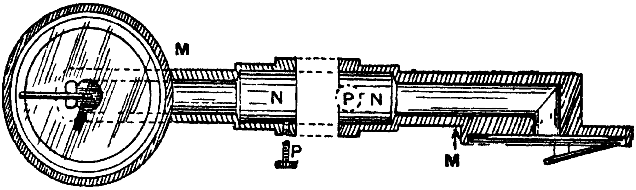

Fig. 94. Fig. 95.

Figs. 94 and 95.—Two Sections of Gramophone-type Recorder.

the spirit to evaporate from the warm metal; after the second coat, heat strongly until the lacquer runs free from brush marks.

Simple Floating-type Recorder.—Figs. 97 and 98 show a simple form of recorder. The disc is as before, except for the recess at the back of the central hole, which is here unnecessary, and in this case $\frac{1}{8}$ in. of the tube's diameter is filed away for a length of 1 in. The filed portion is soldered on the back of the body, the end being chamfered slightly and closed by a shaped disc of brass Q.

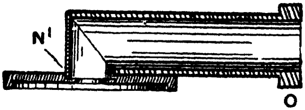

Fig. 96.—Built-up Recorder.

This pattern of recorder can be made without the use of the lathe and with simple tools, the body (not recessed for the diaphragm) being of slighter metal, say, $\frac{1}{16}$-in. to $\frac{3}{32}$-in. brass, cut out with a fret saw or cold chisel, and filed to shape. Before assembling, the metal should be annealed by heating to redness and quenching promptly. This reduces the resonance of the brass to a considerable extent, which is important, as the diaphragm only is required to vibrate under sound stresses.

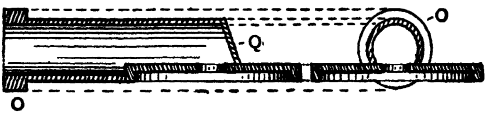

Fig. 97. Fig. 98.

Figs. 97 and 98.—Simple Floating-type Recorder.

Glass, mica, or carbon diaphragms are available for this recorder, the first-mentioned being most generally in use. The size required is $1\frac{5}{16}$ in. in diameter. Half a dozen or so, of various thicknesses, should be procured. Varying qualities and powers of tone require different substances of glass. A full bass voice may cause a thin diaphragm to blast, and often a small tenor voice will produce barely audible results with a thick glass.

The making of disc records is considered outside the ordinary amateur's scope; but it may be here noted that the recording diaphragm for a disc machine may be similar to the floating-type recorder used for phonographs. In Fig. 99, A represents the stem to connect with the trumpet, or, through a ball-and-socket joint, with the tone-arm; B is the cell or body of the recorder; C is the rubber gasket (shown black), on which is mounted the diaphragm D, of glass or mica; E is the sapphire cutter and its holder, secured to the diaphragm with Seccotine or white wax. The diaphragm must not touch the metal of its cell at any point.

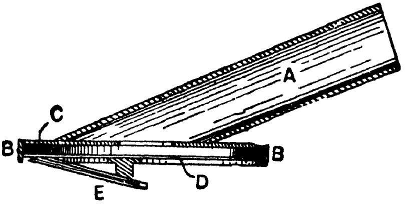

Fig. 99.—Recording Diaphragm for Gramophone.

CHAPTER XV

Moulding Phonograph Wax Cylinders

THE moulding of blank cylinders for the phonograph cannot be successfully carried out at home. The operation is one requiring skill and much experience, apart from the need of a special plant. Only disused blanks are available for re-moulding; old gold-moulded records are useless for the purpose.

Through the courtesy of Mr. Henry Seymour, the following particulars have been supplied: The cylinder mould, which is commonly of brass, is constructed in two parts, the outer cylinder and the core (Figs. 100 and 101). The core (Fig. 101) is hollow, to permit of the free circulation of air for cooling purposes; it is also provided with a handle A. The base of the core at B fits snugly within the base of the cylinder (Fig. 100), and the top of the latter is expanded into a short funnel as shown. A projecting helix (not shown) encircles the core.

The moulding operation is conducted as follows: The core and cylinder are assembled after treatment with graphite powder or French chalk; they are then dipped together into the molten preparation. The compound mould is left immersed for some time, so that it becomes gradually heated by the mixture, and thus the retention of air-bubbles within the mould is avoided. After a time the mould is lifted by the handle, drained, and set to cool. The conical mouth of the mould retains a surplus or "head" of wax, sufficient to consolidate the lower stratum, and to provide for the shrinkage that occurs on cooling.

At a certain stage of the cooling (to be determined only by experience), the core is loosened and twisted out; if allowed to remain too long, the wax will contract and bind the core too tightly for removal. The outer cylinder containing the blank is allowed to cool completely, when the latter will easily slip out. The interior of the blank is next reamered out to calibre with a special tool, after which it is mounted on a mandrel and the conical head turned off. Finally, the cylinder is "shaved" on a machine designed for the purpose; that is, it is turned to truth as

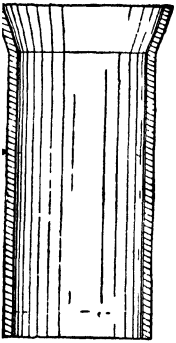
Fig. 100.—Body of Mould.

Fig. 101.—Core to fit inside Cylindrical Body.

metal is turned in a self-acting lathe. The shaving attachment of an ordinary phonograph is quite useless for the purpose.

From the above particulars it will be seen that the home manufacture of blanks need only be attempted by those used to exact and critical operations generally, and who are prepared to make a considerable outlay on plant.

A good standard formula for cylindrical blanks is as follows: Pure stearic acid, 12 lb.; caustic soda, 1 lb.; aluminium oxide, 1 oz.; and tempering (cerasin or paraffin), 2 lb. The caustic soda is boiled in about twice its weight of water, at which point the aluminium oxide is added. The soda lye is now added to the stearic acid, which should have already been melted, and the whole is kept cooking until all the water from the soda is driven off. When this is clear, the tempering is added. The whole is then further heated; the temperature should be about 450° F. (not more, for fear of flashing). This is then strained, lowering the temperature by about 100°. The mixture is then ready for the moulds. It is not quite suitable for master records, but is good for direct reproductions.

CHAPTER XVI

Continuous Forward-wind for Edison "Gem" Phonograph

THE question as to how an Edison "Gem" phonograph may be altered to permit of its being wound while running is of considerable interest to the numerous owners of machines of the type that is fitted with a reversed wind; that is, one in opposition to the running of the gear. The advantages of the forward-wind for a talking-machine of any type are too obvious to require comment.

The alteration may be simply effected without especial skill, and with few tools; the instructions are adapted to the needs of those not possessing a lathe, but, of course, if this is available, the work is much simplified. None of the existing gear need be discarded, except, perhaps, the mainspring, and no extra parts are required but a spring barrel.

Allow the machine to run completely down, and detach the baseboard by removing the four screws, then mark the base to insure its being replaced correctly, and uncouple the speed regulator by slacking off its set screw. Remove the governors by backing the centre pin after loosening the set screw, and run off the belt. Then reverse the machine and remove the four top screws which secure the motor to the base casting. Remove the motor, and, holding the gears steadily in the left hand. wind the spring sufficiently to clear it from the limit pegs; then secure it with a cramp, such as clock-jobbers use for the purpose; or, if one is not available, bind the spring with a few turns of stout wire. Allow the gear gently to again run down as far as it will, but do not allow the wheels to race.

Next loosen the set screws of the belt-wheel and third cog-wheel (which run outside the motor frame on each side) and remove them. Note the relative positions of the remaining gears, and then take down the frame by removing the screws. All parts, including the second wheel, the third pinion, etc., should be put in a place of safety.

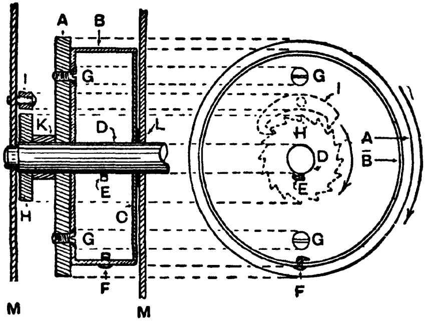

Fig. 102. Fig. 103.

Figs. 102 and 103.—Continuous Forward-wind for Edison "Gem" Phonograph

The great wheel, with its long winding-stem and cramped spring, must be carefully handled. Be sure not to detach the wire binding which confines the spring, or the latter will violently uncoil, endangering the teeth of the great wheel. and probably causing the loss of several knuckles. Slip the loop at the outer end of the spring gently off the frame-pillar, and draw the winding-stem from its bearing. Then cautiously disconnect the spring from the spur on the axle (by turning the latter backwards), and draw it off. The great wheel may also be taken off, leaving the ratchet wheel only on the axle. This must be removed, reversed, and remounted at the end of the axle, so that it may be close to the frame with its teeth sloping in the opposite direction (see H, Fig. 102). The ratchet must be removed from the side of the great wheel and mounted on the frame as at I. When reassembled, the great wheel must occupy its former position on the axle, and the space between it and the ratchet wheel must be made up by a turned metal sleeve or a number of small washers K. The spring spur E (Figs. 102 and 103) on the stem must be reversed so as to face in the opposite direction; or it may be punched out and replaced by another.

A spring barrel may possibly be picked up at a clock-jobber's; but a suitable one will probably be difficult to find. The extreme dimensions permissible are 2¼ in. in diameter by ¾ in. deep. Procure a cutting of this width from a stout brass tube of this diameter. Also get a piece of stout sheet brass, say $\frac{1}{16}$ in. thick, from which two discs 2¼ in. in diameter may be cut. Beat the brass all over on an anvil with a smooth-faced hammer to harden it, then strike two circles of the exact inner diameter of the tube-cutting, and cut out the circles. If too tough for cutting with shears, use a cold chisel. Then flatten out and file both carefully to fit the barrel tightly, and bore central holes in each disc to fit the winding stem.

Clean the inner side of the tube with glasspaper, drive one of the discs into it perfectly flush and square, and solder. This is best done over a gas-ring. Thoroughly dress the joint with soldering fluid (zinc chloride), heat up, again apply fluid, and place a few small pieces of solder within the drum; heat strongly until the solder flushes the seam, cool, wash, and dry off.

Two holes must now be bored and countersunk in the side of the drum, to take the two screws which attach it to the great wheel, in which holes are bored and tapped to receive them. If preferred, rivets may be substituted; in each case the heads must be kept flush with the inner side of the drum (see G). In the rim of the drum is fixed a spur, to engage the slot at the outer end of the spring. This spur must face in the direction indicated at F, which shows the drum from the key or handle side, the disc C being removed. Or this spur may be formed in the metal of the drum itself, a small, tongue-shaped piece being neatly cut and bent inwards. Reference to the illustrations will make the foregoing instructions clear.

In Fig. 102 the main wheel, drum, and axle are represented assembled and mounted between the frames M. The great wheel A is attached to the drum B by means of the screws G. The wheel and drum revolve together on the axle or winding-stem D in the direction indicated by the arrow in Fig. 103. It will be observed that the wind and drive are now in the same direction. The mainspring (not shown) hitches on to the spurs E and F on the axle D and the drum B respectively. The ratchet wheel H is secured to the end of the axle D, and is engaged by the ratchet I, which is now attached to the frame M.

The detachable disc c is forced level with the rim of the drum after the spring is slipped in.

The spring must be strong, but somewhat shorter than the existing one; it must also be narrower, so that it may not bind against the drum sides. A suitable one can be selected from the stock of any dealer in phonograph accessories. When purchased, the spring will be rolled up and secured with wire or a cramp; it must be inserted in the barrel in this condition (taking care it is the right way about), and the wire gradually slipped off. When inserted, revolve the axle by its key until the spur E enters the slot at the inner end of the spring; then turn the drum round until its spur F engages with the slot at the spring's outer extremity.

Before forcing in the disc c, fill up the spring coils and drum with a smooth mixture of unscented vaseline and pure graphite (plumbago or blacklead, sold by most chemists). Carefully reassemble the machine, putting a thin sheet-metal washer between the detachable disc c and the frame M, as at L. The space between the great wheel and the ratchet wheel is occupied by a sleeve, or made up by washers K, leaving a little side-play. Treat all the wheel-work with the lubricant mentioned above. Although it will never congeal or clog the movement, it will be found an admirable silencer of cogged gear. Wind up and run down the machine several times to distribute the grease among the spring coils within the drum.

In its altered condition, the machine will probably not run two records as before, but this is no drawback.

as it can now be wound while running. The operator will soon acquire the habit of giving an occasional turn to the key, thus keeping the motor running continuously after the first full wind. Make it a practice to run the machine down before putting it aside; the lives of both spring and gear are thus much extended.

INDEX

ALUMINIUM horns, 62
Arm, tone, 27-29
Articulated elbow, 87
Auxeto pneumatic reproducer, 25-27

BALL-STYLUS, 34
Bell, Prof., 4
Berliner, H., 4
Blanks for record making, 114
Brake for motor, 101
Brass horns, 62, 69-72
—— instruments, recording, 129, 130
Button-stylus, 33, 34

CARBON used for diaphragms, 22
Cardboard horns, making, 72-74
Case for gramophone, 80-83
'Cello, recording, 128
Choice of machine, 7
Chronophone, Gaumont, 6
Clarinet, recording, 130
Columbia sound magnifier, 29-31
Continuous forward-wind for Edison "Gem" phonograph, 144-149
"Convolvulus," or flower horns, 55
Copper horns, 62
Cylinders, moulding wax, 141-143
Cylindrical blanks, standard formula for, 143
—— records, 34
—— reproducer, stylus of, 33

DIAPHRAGMS, 16
——, setting, 17, 18
—— and styli for recording, 111, 140
——, substances used for, 21-23
Disc machines, 5, 6
—— records, 3
—— reproducer, stylus of, 34
—— sound boxes, 18

Domes and spiders, 47
Drilling plates, 103
"Drum-head," 16

EDISON "Gem" machine, fitting continuous forward-wind to, 144-149
—— —— ——, —— floating reproducer to, 48
—— —— ——, —— speaker-arm to, 49-53
—— phonograph, 10
—— recorder, 111, 112
—— reproducers, 10, 20, 23, 24, 33
Elbow, articulated, 87
Excelsior machines, 10

FLARES for horns, 68, 73, 74
Floating recorder, 112, 113
—— reproducer, 10, 11, 20, 44-48

GAUMONT chronophone, 6
Glass for diaphragms, 22
—— reproducer discs, 47, 48
—— stylus, 35, 36
Governor, 104
—— pinion, 100
Gramophone Co.'s "Exhibition" sound boxes, 19, 20
—— —— tone-arm, 86, 87
"Gramophone" and "Graphophone": derivation of words, 4, 5
Graphophone recorder, 111, 112

"HORNLESS" gramophone, 92, 93
Horns, 54-79
——, aluminium, 62
——, angle of, 54, 55
——, balance of, 60
——, brass, 62, 69-72
——, cardboard, 72-74
——, "convolvulus" or flower, 55
——, copper, 62
——, flares for, 68, 73, 74
——, home-made, 58-62

Horns, iron, 62
——, large, fitting, 58
——, length of, 56, 57
——, materials for, 62
——, octagonal, 69-72
——, paper, 75-79
—— for record making, 110, 111
——, recording, double Y-union for, 131
——, tinned iron, 62
——, tinplate, 63-72, 91
——, wood and wood-pulp, 62

IRON horns, 62
Instruments, recording, 128-131
Ivory diaphragms, 23

LUBRICATING talking machines, 13-15

MAINSPRING of motor, 104
Metal diaphragms, 23
Mica diaphragms, 22
—— discs, cutting, 22
Motor, constructing, 94-104
——, correct speed of, 8
——, fitting new springs to, 105-107
Moulding wax cylinders, 141-143

NEEDLE and stylus, 32-37

OCTAGONAL horn, 69-72

PAPER horns, making, 72-74
Pathé machines, 10
"Phonograph": derivation of word, 5
Phonograph (*see* "Edison")
Piano records, making, 126-128
Pinion, governor, 100
Plates, drilling, 103
Prices of talking machines, 10, 11
"Puck" phonograph, 11

RECORD, cylinder, 3, 4
——, disc, 3
—— making, 108-132
—— ——: band, 131, 132
—— ——, blanks for, 114
——, ——: brass instruments, 129, 130
—— ——: 'cello, 128
—— ——: clarinet, 130
—— ——, faults in, 118, 119
Record making, horn used for, 110, 111
—— ——: instrumental duets, 130, 131
—— ——, machine for, 110
—— ——: piano, 126-128
—— ——, resonators for, 123-125
—— ——, room for, 116
—— ——: singing, 117, 123-126
—— ——: speeches, 117, 119-122
—— ——: stringed instruments, 128, 129
—— ——, styli for, 113, 114
—— ——: violin, 128
—— ——: whistling, 116, 118
—— ——: wind instruments, 128, 129
—— ——: "wiping," 115
—— ——: wood - wind instruments, 130
—— removing, by shaving, 115, 116
Recorders, 133-140
——, Edison's, 111, 112, 133-137
——, graphophone or floating, 112, 113, 137-139
Recording diaphragm for disc machine, 140
—— —— and styli, 111
—— horns, double Y-union for, 131
Reproducer, Auxeto pneumatic, 25-27
—— discs, glass, 47, 48
——, Edison, 10, 20
——, floating, 10, 11, 20, 44-48
——, making, 38-43
——, Seymour, 21, 48
Resonators for making vocal records, 123-125

SAPPHIRE stylus, 33, 114
—— ——, renewing, 92
Seymour: moulding cylinders, 141
—— reproducer, 21, 48
Shaving record, 115, 116
Singing, recording, 117, 123-126
Socket, trumpet, 89, 90
Sound boxes, disc, 18
—— ——, "Exhibition," 19, 20
—— magnifier, Columbia, 29-31
——, recording, 1, 2, 108, 109
—— reproduction, principles of, 1, 2
—— waves, 1, 2
Speaker-arm, 49-53

"Speakers," 16-31
Speeches, making records of, 117, 119-122
Speed regulation, 14
Spiders, 47
Spring drum, 97, 98
—— motor, constructing, 94-104
Springs of motor, 101
——, new, inserting, 105-107
Stringed instruments, recording, 128, 129
Stylus, ball, 34
——, button, 33, 34
—— for cylinder reproducer, 33
—— of disc reproducer, 34
—— for Edison reproducer, 33
——, glass, 35, 36
—— holder, 136, 137
—— for record making, 112-114
——, sapphire, 33, 114
——, ——, renewing, 92
Stylus, steel, 113, 114
——, wear on, 34, 35

TABLE for motor, 100
Tinplate horns, making, 63-72, 91
Tone arm, 27-29
—— ——, Gramophone Company's design of, 86, 87
Trumpet socket, 89, 90
—— stem, 87, 99
Trumpets (*see* Horns)

VIOLIN, recording, 128

WAX cylinders, moulding, 141-143
Whistling, recording, 116, 118
Wind instruments, recording, 128, 129
"Wiping" records, 115
Wood and wood-pulp horns, 62

Made and Printed in Great Britain by
The Greycaine Book Manufacturing Company Limited Watford
30.527

Cassell's Famous Gardening Handbooks

Should be the constant companions of the gardener, whether amateur or professional. These Books are thoroughly practical, up to date, and the illustrations are abundant and beautiful.

1/6 Each net

or 1/9 post free from
CASSELL'S
Publishers, London.

- *Plant Pests and Diseases*
- *Dahlias, Gladioli and Begonias*
- *Chrysanthemums for the Amateur*
- *Allotment Gardening: A Complete Guide*
- *Bulb Growing for Amateurs*
- *Everybody's Flower Garden*
- *First Steps in Gardening*
- *Fruit Growing for Amateurs*
- *Garden Handbook for Beginners*
- *Garden Planning and Planting*
- *Garden Work for Every Day*
- *Gardening: A Complete Guide*
- *Gardening Difficulties Solved*
- *Hardy Border Flowers*
- *Indoor Gardening*
- *Little Gardens: How to Make the Most of Them*
- *Popular Guide to Gardening*
- *Rockeries: How to Make and Plant Them*
- *Rose Growing for Amateurs*
- *Sweet Peas and How to Grow Them*
- *The Carnation Book*
- *The Garden: How to Make It Pay*
- *The Garden Month by Month*
- *The Greenhouse: Its Flowers and Management*
- *1,000 Gardening Hints*
- *Vegetable Growing for Amateurs*

CASSELL'S
Publishers, London.

"AMATEUR WIRELESS" HANDBOOKS

2/6 Each Net. *Of all Booksellers, or by post plus 3d. extra from Cassell & Co., Ltd., London.*

THE SHIELDED FOUR-ELECTRODE VALVE.

By Capt. J. H. Round.

Contents: The General Problem—Tuning and Amplification—Triode Characteristics—Tetrode Characteristics—H. F. Amplifier with the Tetrode—Circuits—High Quality—Some Possible Circuits and the Super Hetrodyne—Short-wave Receivers—Single-handed Controls.

PRACTICAL SUPER-HET BOOK.

Contents: What the Super-het Does—The Intermediate Transformers—Design and Equipment—Faults and Their Remedies—The Tropadyne Six-valve Super-het—A Seven-valve Super-het—A Three Unit Super-het—An Ultradyne Eight-valver.

LOUD SPEAKER CRYSTAL SETS.

Contents: Chief Consideration in the Design of Loud-speaker Sets—A Simple Variometer Crystal Receiver—Other Variometer Crystal Sets—Crystal Sets for Indoor Aerial—A Combined Single-slider and Loose-coupled Set—A Simple Fixed-couple Set—A Single Coil Loud-speaker Set—Loud-speaker Variometer Crystal Set—Loud-speaker for Use with Crystal Sets—Variometer Set with Loading Coil—A Tapped-inductance Set with Loading Coil—An All-wavelength Receiver—Set with Air-spaced Loose-coupled Tuner—The "A.W." Self-contained Loud-speaker Crystal Set—Making the "A.W." Self-contained Loud-speaker Crystal Set—"A.W." Loud-speaker Unit for attachment to any Crystal Set.

THE WIRELESS MAN'S WORKSHOP.

Contents: Tools for Wireless Work—Cutting and Finishing Panels—Marking Out Panels—Drilling—Tapping—Fitting Components—Soldering—Wiring—Workshop Hints and Tips—Woodworking—Coil Winding—Repairing Wireless Components—The Well-ordered Workshop—Useful Facts and Figures.

PERFECT BROADCAST RECEPTION.

Contents: A Bird's-eye View of Wireless—The Aerial—Crystal Reception—The Valve Considered—Amplification—Causes of Poor Reception—The Disposition of the Components—A Popular Four-valve Set—Choke Coupling—Resistance capacity Coupling—Battery Coupling—Push-pull Amplification—The Loud-speaker Considered—Improving the Set—Further Facts Concerning Valves.

THE PRACTICAL WIRELESS DATA BOOK.

Contents: Introductory—Inductance and Capacity—Wavelength and Tuning—Condensers—Resistances and Potentiometers—Transformers—The Crystal—Valves—Accumulators and High-tension Batteries—Aerials and Earths—Miscellaneous Facts.

WIRELESS-CONTROLLED MECHANISM FOR AMATEURS.

Contents: General Information—Transmitting Apparatus—Receiving Apparatus — Wireless-controlled Model Airships — Wireless-controlled Model Trains and Boats—Wireless Stage Stunts—Miscellaneous Applications of Wireless Control.

THE SHORT-WAVE HANDBOOK.

Contents: Special Precaution in Short-wave Work—The Design of Short-wave Sets—Short-wave Coils—The Short-wave Aerial and Earth—The Hartley Receiver—The Reinartz Circuit—The Straight Circuit—The Ultra-short Wave—Low-power Short-wave Transmitters—The Wavemeter — A History of the Short Wave — Crystal-controlled Transmitters.

CASSELL'S, LONDON.

Amateur Wireless Handbooks

1/6 each NET

or 1/9 post free
from
CASSELL'S,
LA BELLE
SAUVAGE,
E.C.4

Wireless Telephony Explained

Contents:—The Electron; Induction and Electro Magnetism; Waves and How They Travel; Inductance and Capacity; Rectification; Amplification; Reaction and Beat Reception; Aerials and Earths; Transmitting Systems; Receiving Sets; Useful Formulæ and Data; Index.

Crystal Receiving Sets

and How to Make Them

Contents:—A Simple and Efficient Receiving Set; A Single-slider Set; Set with Semicircular Tuner; Crystal Set with Tapped Single Coil; A Loose-coupled Set; Set with Plug-in Basket Coils; Combined Crystal and Valve Receiver; Some Miniature Receiving Sets; Crystal Circuits; How Crystals Work; Making a Buzzer; Receiving C.W. Signals on a Crystal Set; Converting Low-resistance Phones; The Morse Code; Index.

Wireless Component Parts

and How to Make Them

Contents:—Components and Their Varied Purposes; Crystal Detectors; Coils, Making and Mounting; Condensers; Variometers and Variocouplers; Resistances or Rheostats; Transformers; Making a Test Buzzer; Index.

Wireless Telegraphy and Telephony

and How to Make the Apparatus

This revised edition is by Mr. E. Redpath, the well-known writer on wireless. The explanations of principles are up to date, and there are directions for making apparatus, including detectors, amplifiers, single-circuit and complete short-wave receiving sets, a valve panel, and a five-valve amplifier.

Each Book being Well Illustrated and Thoroughly Practical

Practical Guide to Wireless

(1s. net)

Contents:—An Outline of Present Broadcasting; The Aerial; Tuners and Tuning; The Crystal Set; The Valve and Valve Sets; Telephones and Loud-Speakers; Current for Valve Filaments; Index.

Cassell's, Publishers, La Belle Sauvage, E.C.4.

The "Amateur Mechanic and Work" Handbooks. 9/27. [Cover 3